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Kumagai et al.

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(45) **Date of Patent: May 8, 2001**

(54) **OPTICAL DISC DEVICE AND OPTICAL DISC DISCRIMINATING METHOD**

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(73) Assignee: **Sony Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/143,220**

(22) Filed: **Aug. 28, 1998**

Related U.S. Application Data

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(30) **Foreign Application Priority Data**

Jan. 10, 1997 (JP) 9-014774

(51) **Int. Cl.**[7] **G11B 7/00**
(52) **U.S. Cl.** **369/44.27**; 369/58
(58) **Field of Search** 369/58, 54, 94, 369/44.27, 44.29, 44.41, 44.25

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Primary Examiner—Thang V. Tran
(74) *Attorney, Agent, or Firm*—Andrew V. Smith

(57) **ABSTRACT**

A laser light beam is illuminated via an objective lens on the signal surface of an optical disc and the objective lens is displaced by a servo processor along the optical axis for focussing search to generate focussing error signals by a RF block from a detected output of the laser light by the signal surface of the optical disc. Based on these focussing error signals, a system controller discriminates the types of the optical disc having different numbers of signal recording layers for setting an operating mode in keeping with the types of the optical disc.

18 Claims, 22 Drawing Sheets

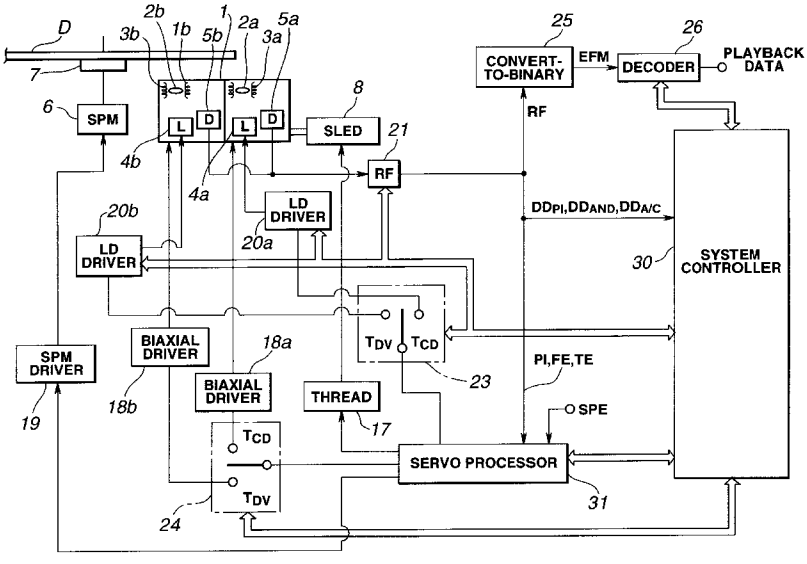


FIG.1A

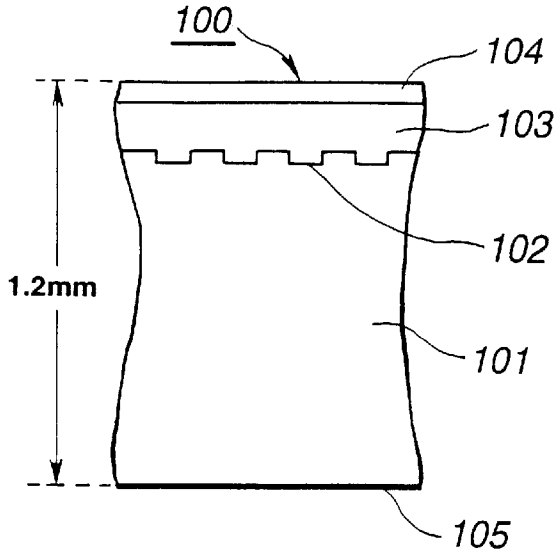


FIG.1B

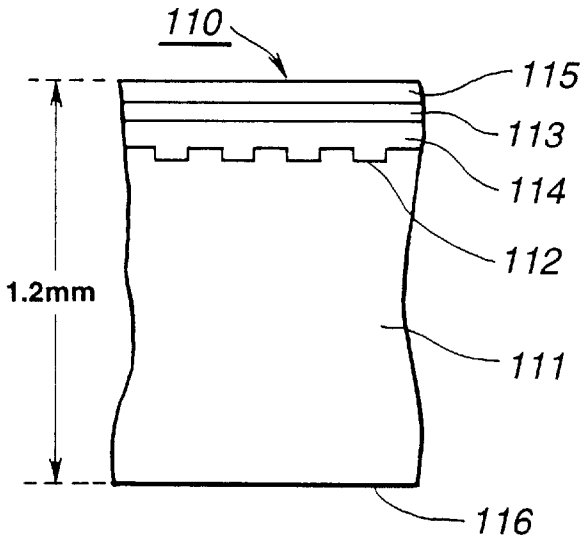
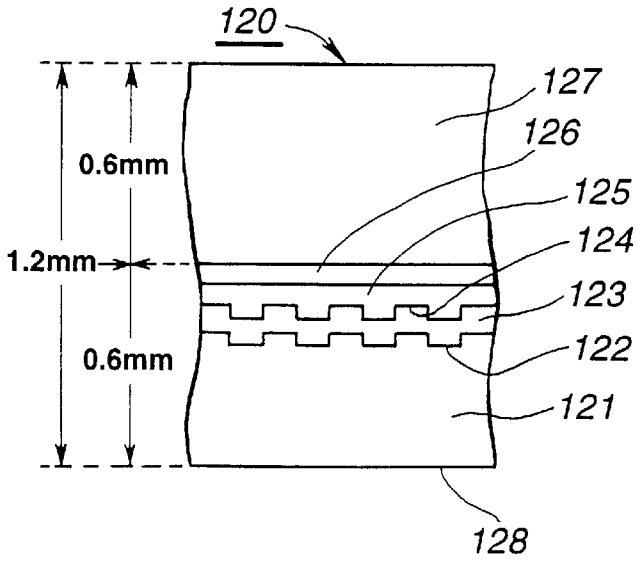


FIG.1C



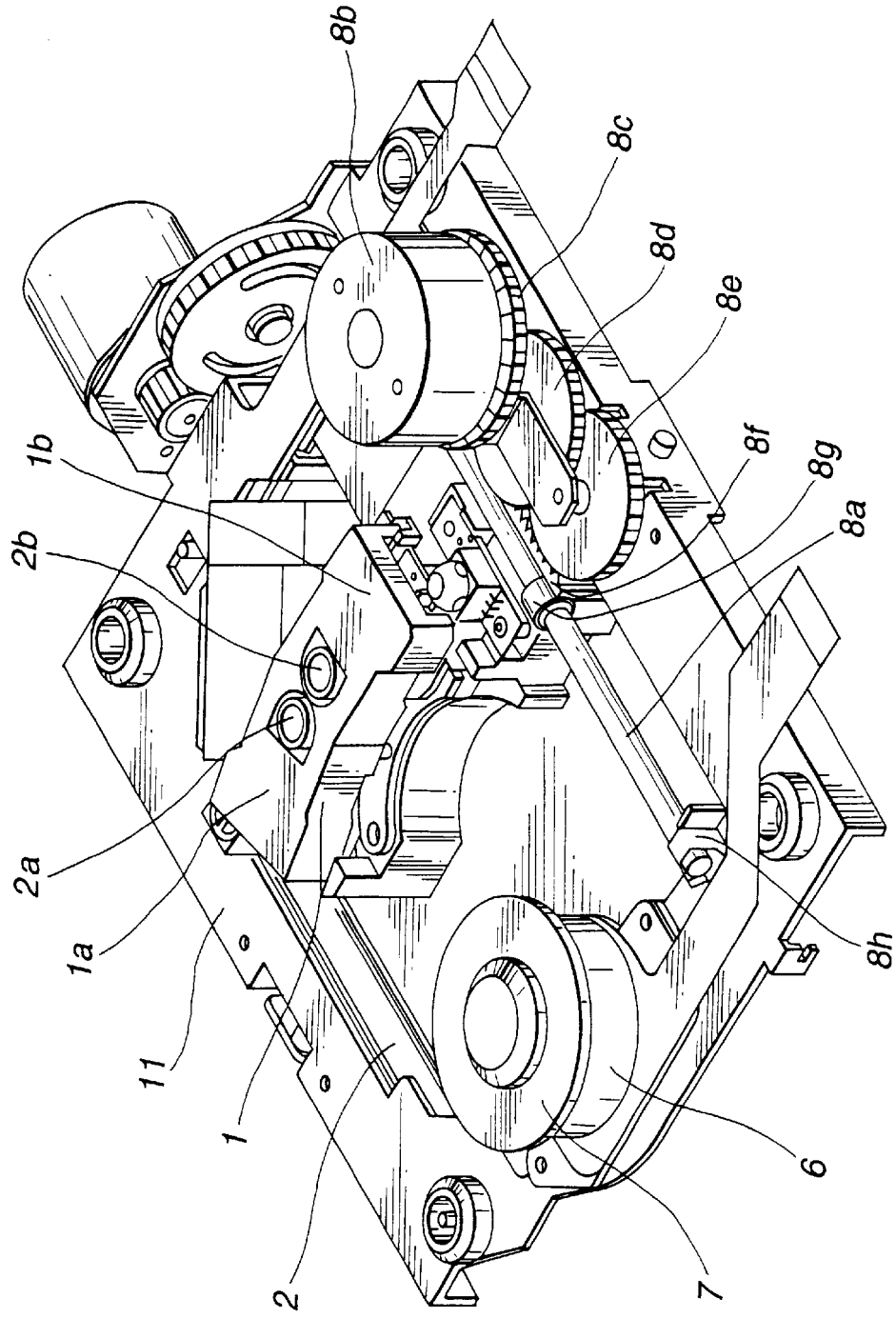


FIG.2

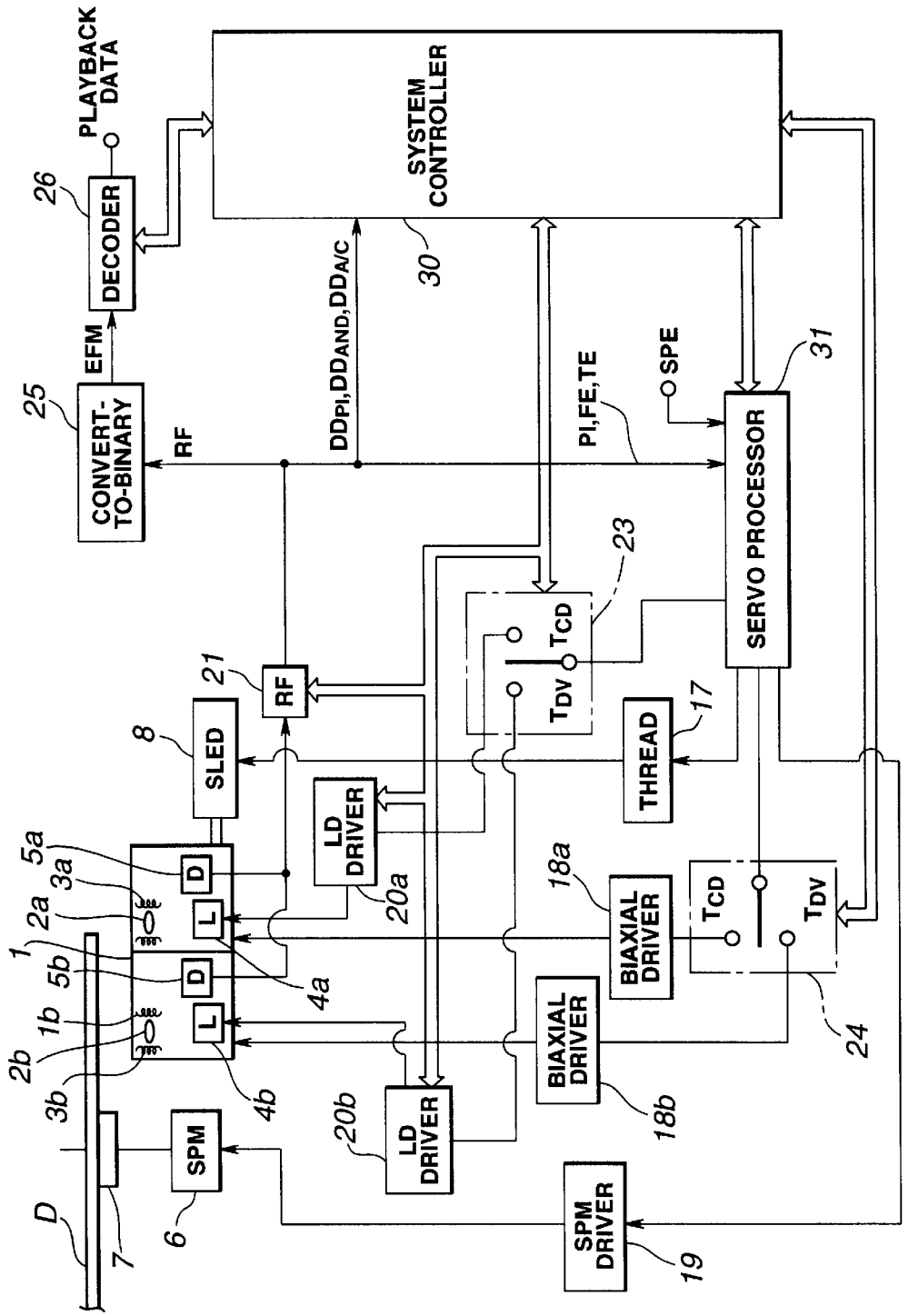

PLAYBACK DATA
SYSTEM CONTROLLER
DECODER
EFM
CONVERT-TO-BINARY
RF
DDPI,DDAND,DDA/C
PI,FE,TE
SPE
SERVO PROCESSOR
TCD
TDV
SLED
RF
LD DRIVER
THREAD
BIAXIAL DRIVER
SPM
SPM DRIVER
D
L
26
25
30
31
23
21
8
17
5a
3a
2a
1
5b
1b
2b
3b
4a
4b
20a
20b
18a
18b
24
6
7
19

FIG.3

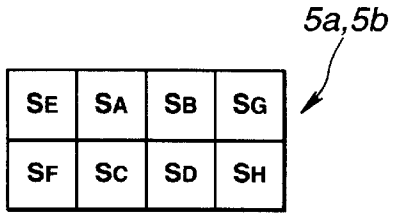

5a,5b
SE
SA
SB
SG
SF
SC
SD
SH

FIG.4

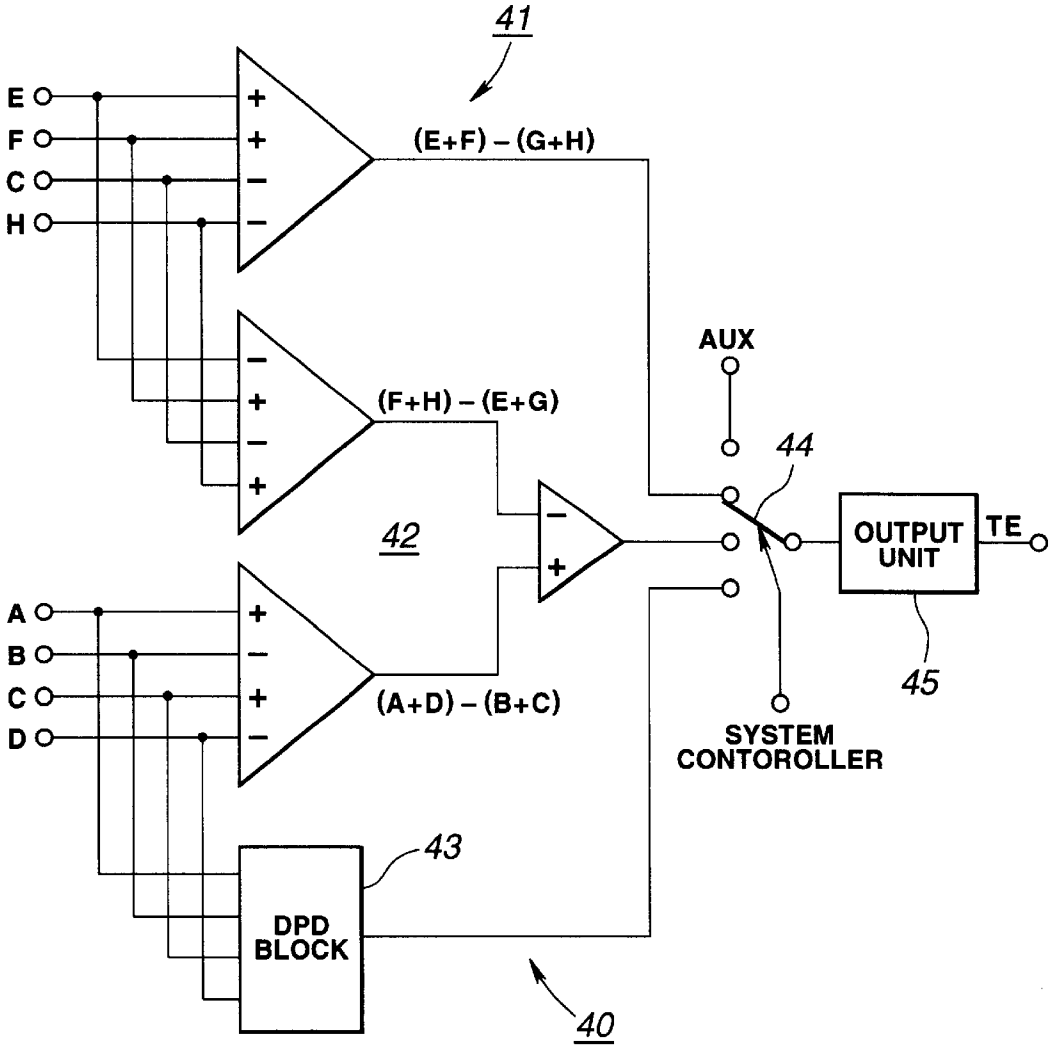

41
E
F
C
H
(E+F) – (G+H)
(F+H) – (E+G)
42
A
B
C
D
(A+D) – (B+C)
AUX
44
OUTPUT UNIT
TE
45
SYSTEM CONTOROLLER
43
DPD BLOCK
40

FIG.5

FIG.6A

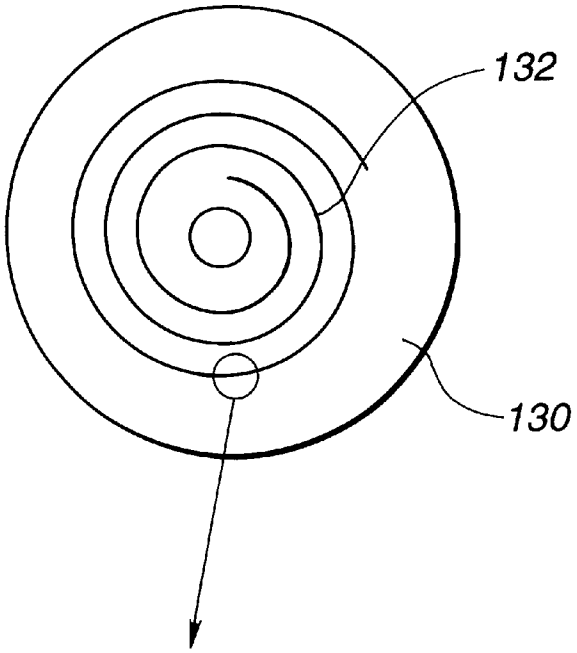
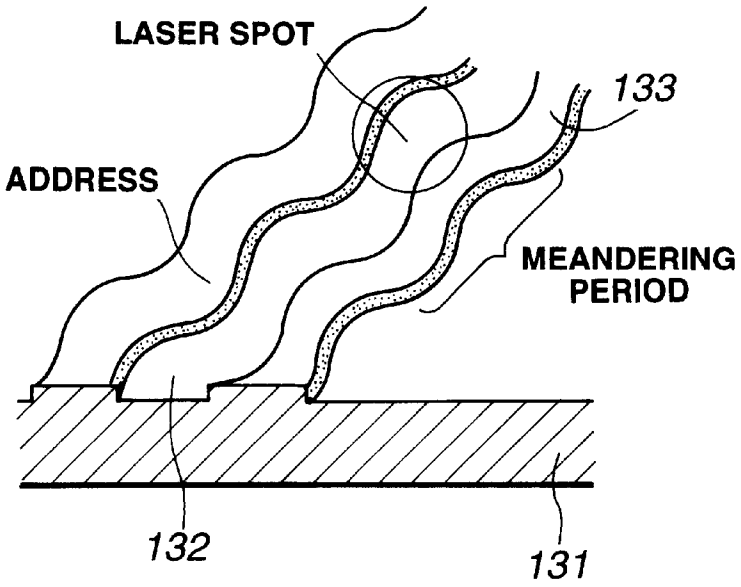


FIG.6B



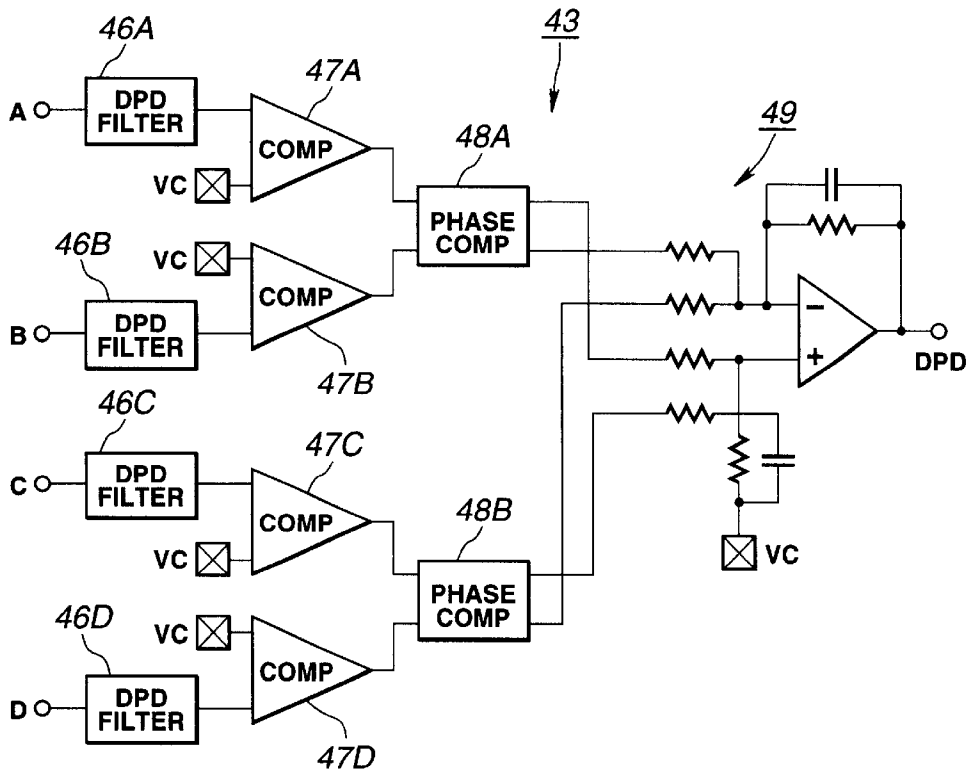

46A
43
47A
A
DPD FILTER
COMP
VC
48A
49
PHASE COMP
46B
VC
B
DPD FILTER
COMP
47B
DPD
46C
47C
C
DPD FILTER
COMP
VC
48B
PHASE COMP
VC
46D
VC
D
DPD FILTER
COMP
47D

FIG.7

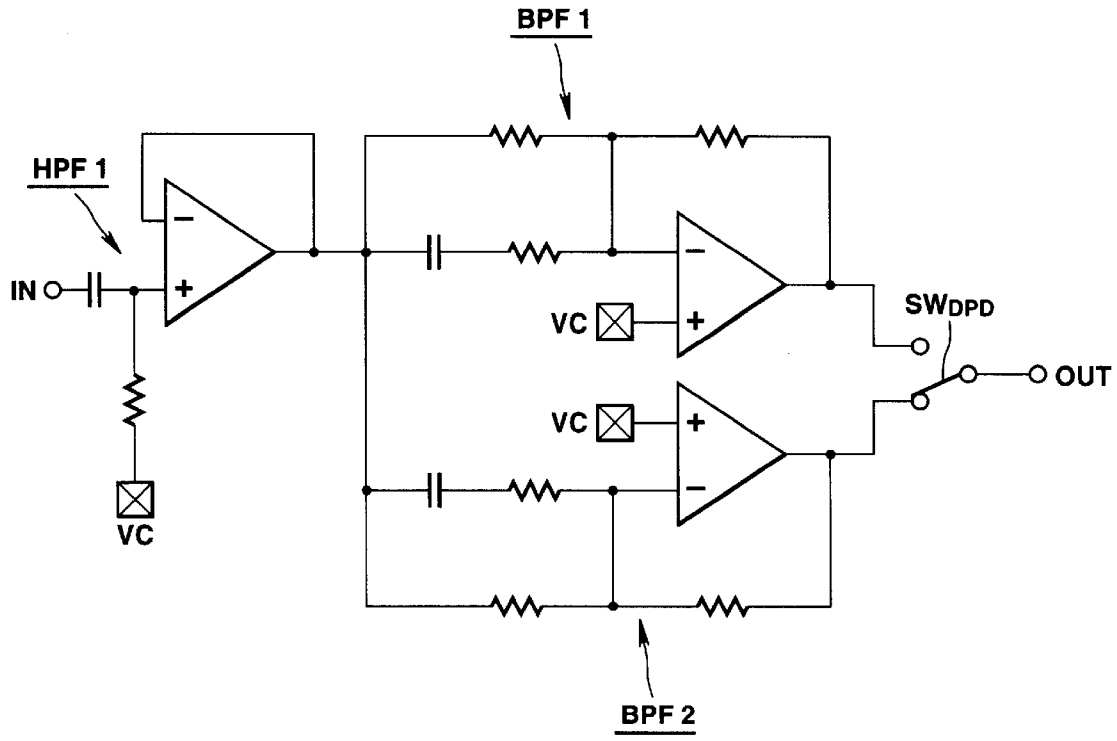


FIG.8

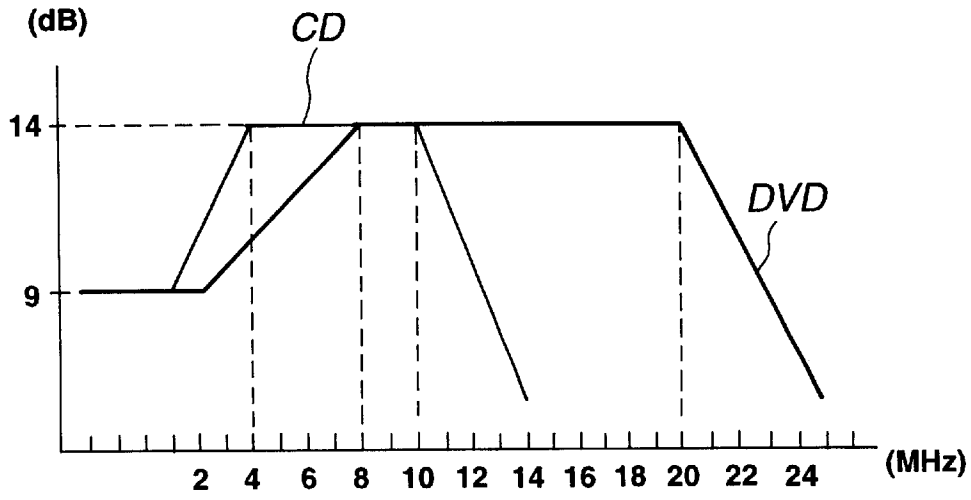


FIG.9

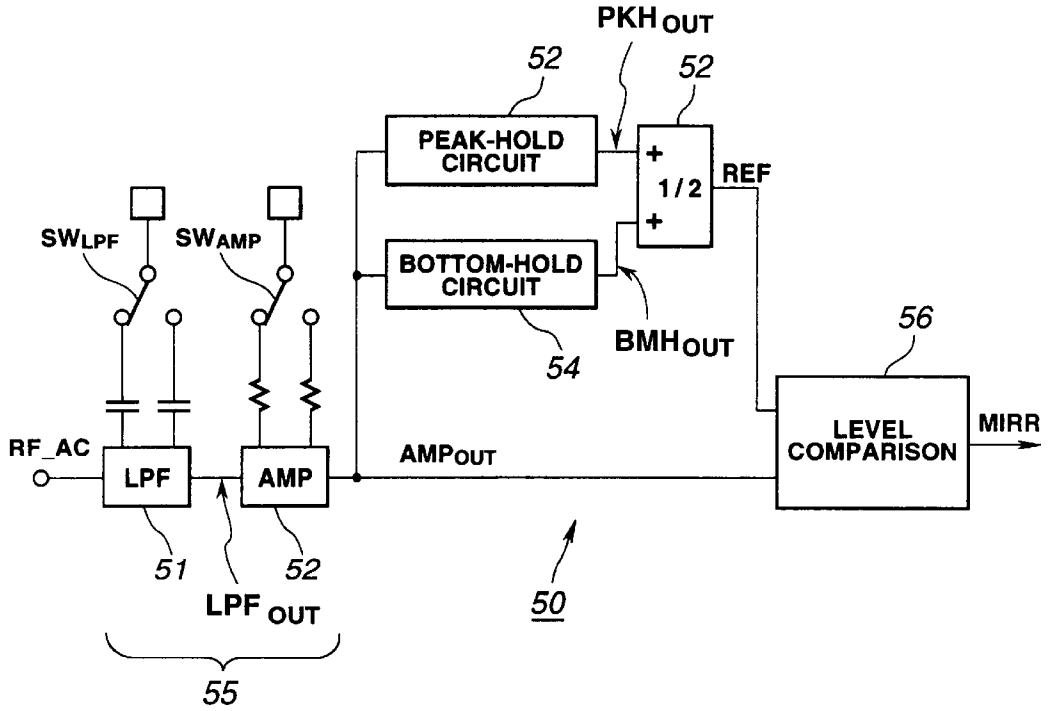

PKH OUT
52
52
PEAK-HOLD CIRCUIT
+
1/2
+
REF
SWLPF
SWAMP
BOTTOM-HOLD CIRCUIT
BMHOUT
56
54
LEVEL COMPARISON
MIRR
RF_AC
LPF
AMP
AMPOUT
51
52
LPF OUT
50
55

FIG.10

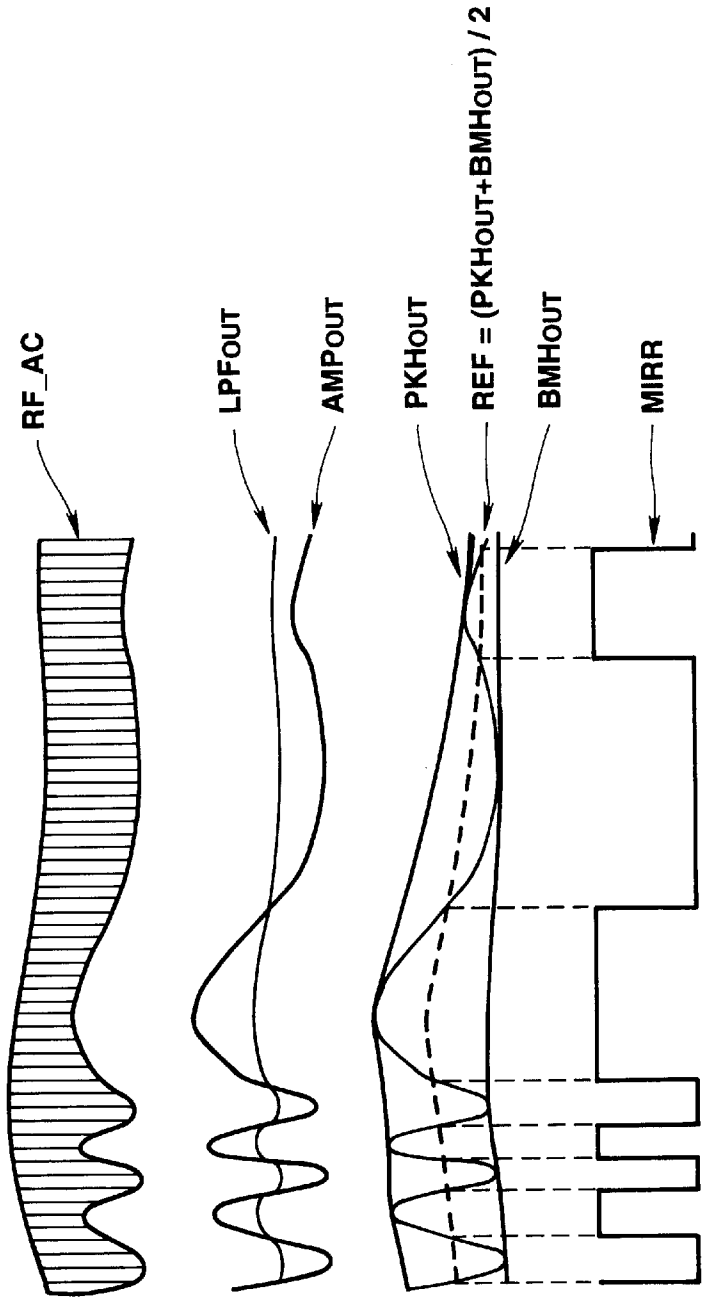


FIG.11A FIG.11B FIG.11C FIG.11D

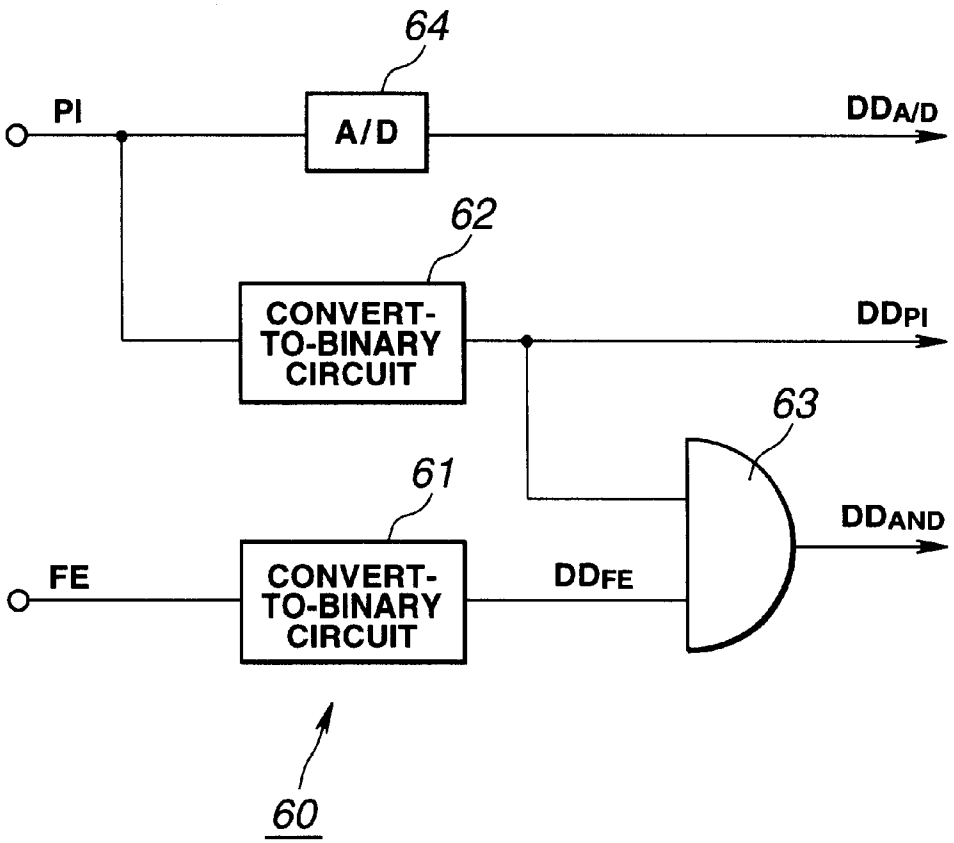

64
PI
A/D
DDA/D
62
CONVERT-TO-BINARY CIRCUIT
DDPI
63
61
DDAND
FE
CONVERT-TO-BINARY CIRCUIT
DDFE
60

FIG.12

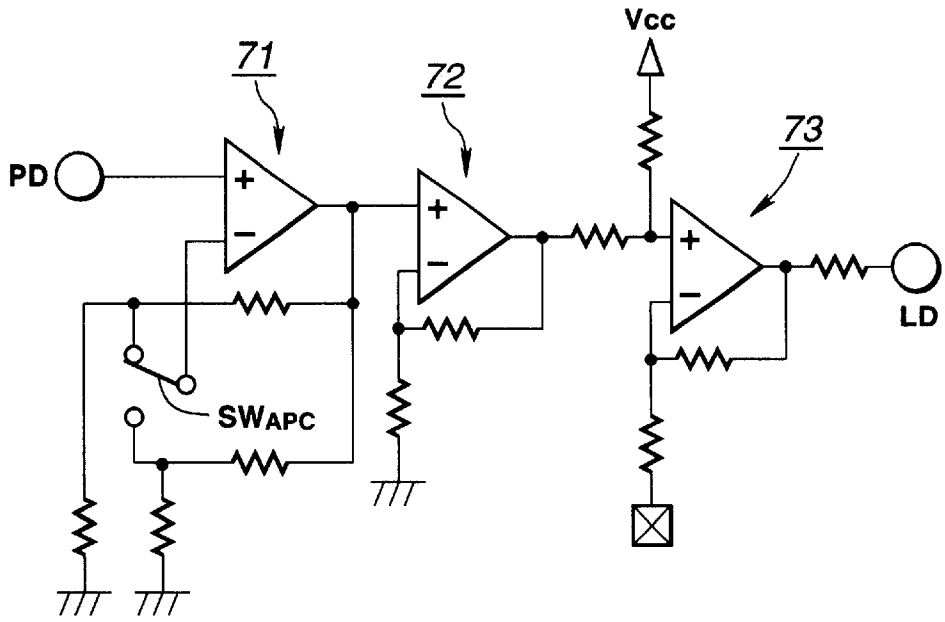


FIG.13

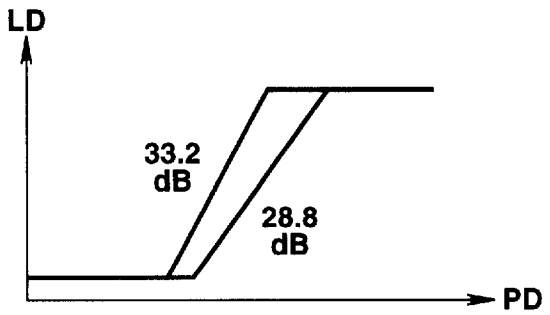


FIG.14

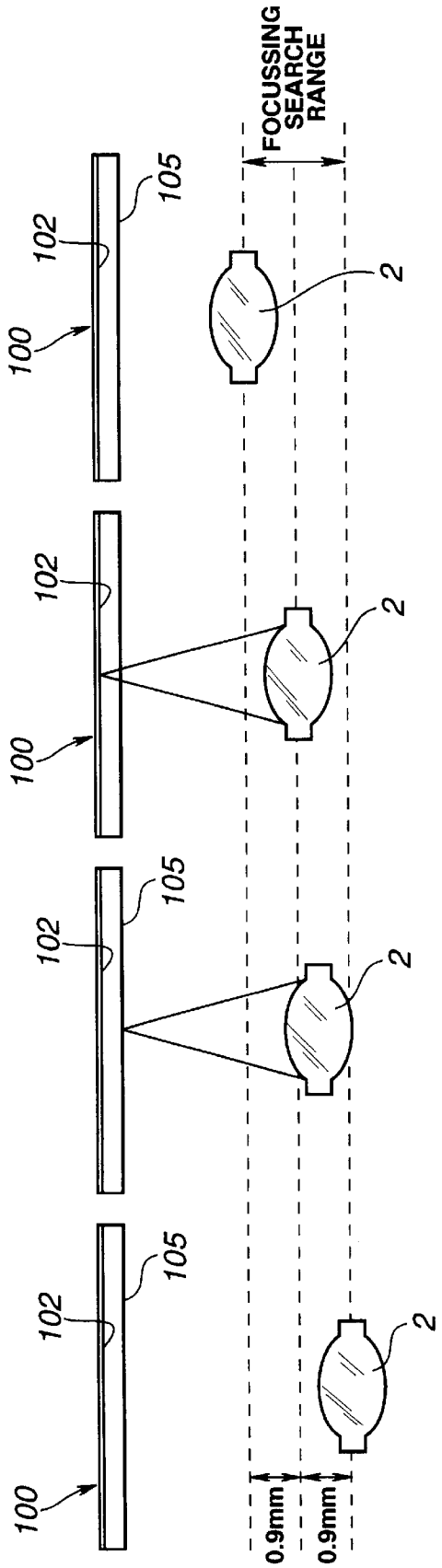


FIG.15A FIG.15B FIG.15C FIG.15D

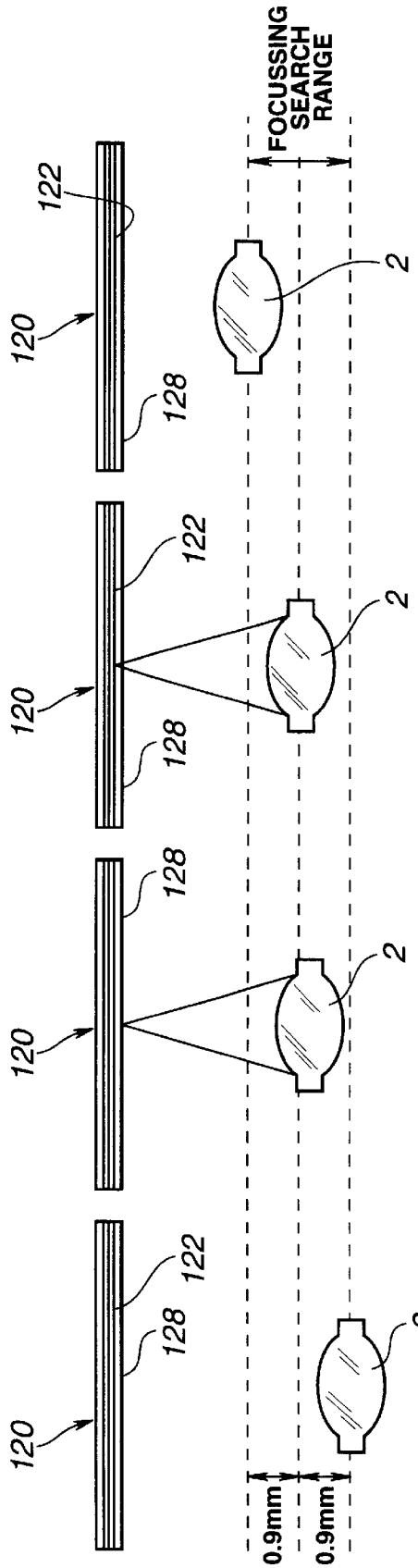


FIG.16A FIG.16B FIG.16C FIG.16D

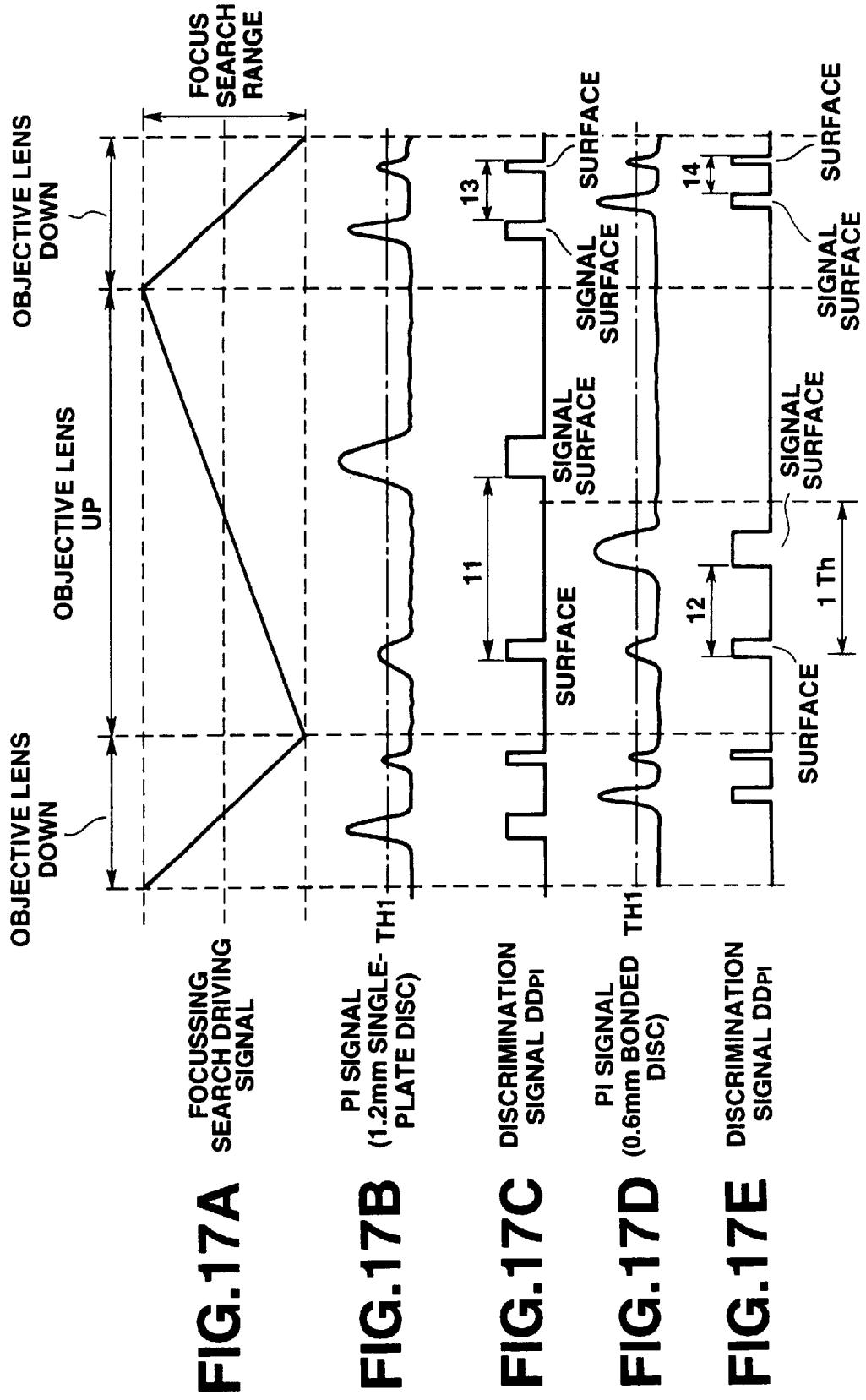


FIG.17A

FIG.17B

FIG.17C

FIG.17D

FIG.17E

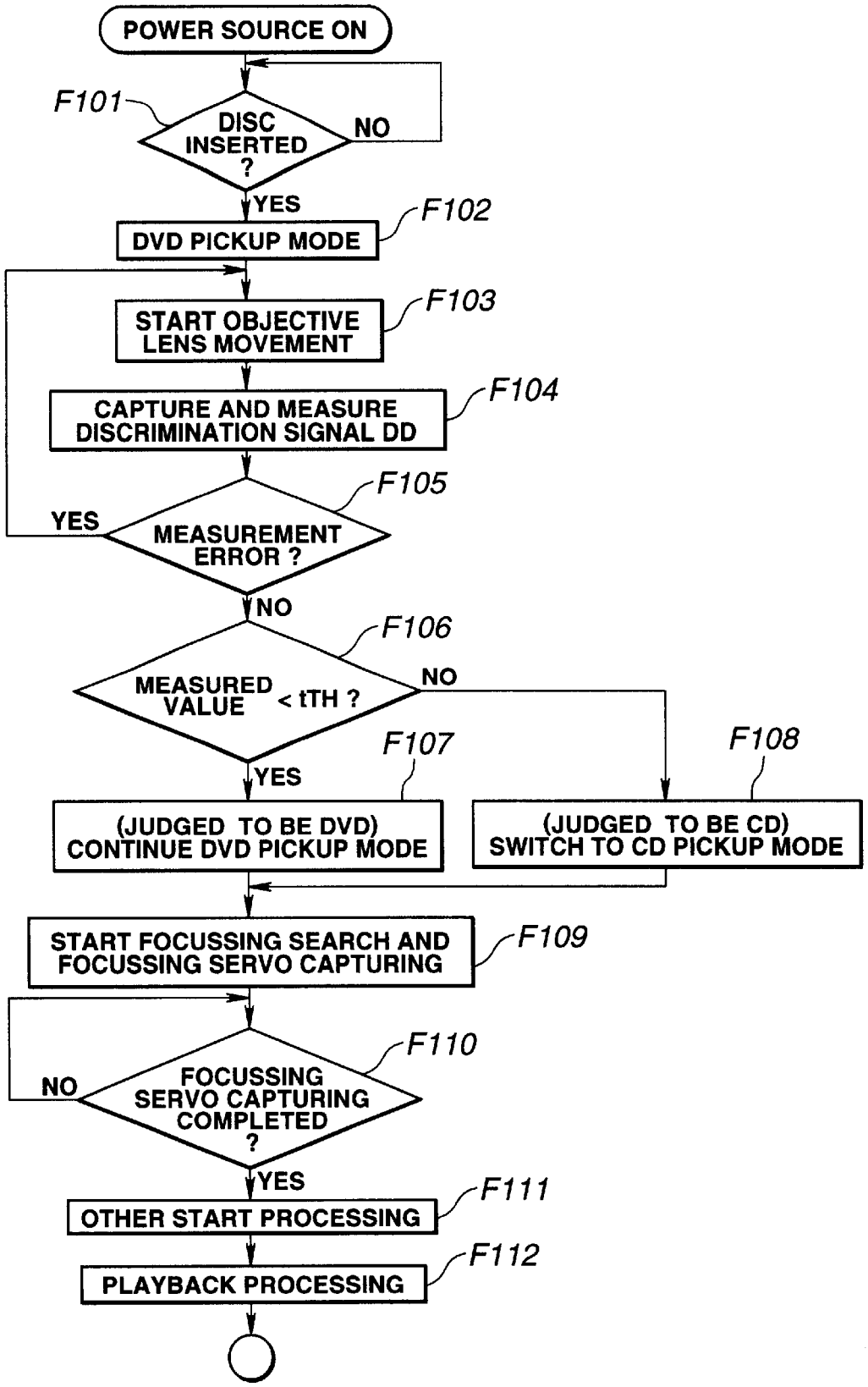

POWER SOURCE ON
F101
DISC INSERTED ?
NO
YES
F102
DVD PICKUP MODE
F103
START OBJECTIVE LENS MOVEMENT
F104
CAPTURE AND MEASURE DISCRIMINATION SIGNAL DD
F105
YES
MEASUREMENT ERROR ?
NO
F106
MEASURED VALUE < tTH ?
NO
YES
F107
(JUDGED TO BE DVD) CONTINUE DVD PICKUP MODE
F108
(JUDGED TO BE CD) SWITCH TO CD PICKUP MODE
START FOCUSSING SEARCH AND FOCUSSING SERVO CAPTURING
F109
F110
NO
FOCUSSING SERVO CAPTURING COMPLETED ?
YES
F111
OTHER START PROCESSING
F112
PLAYBACK PROCESSING

FIG.18

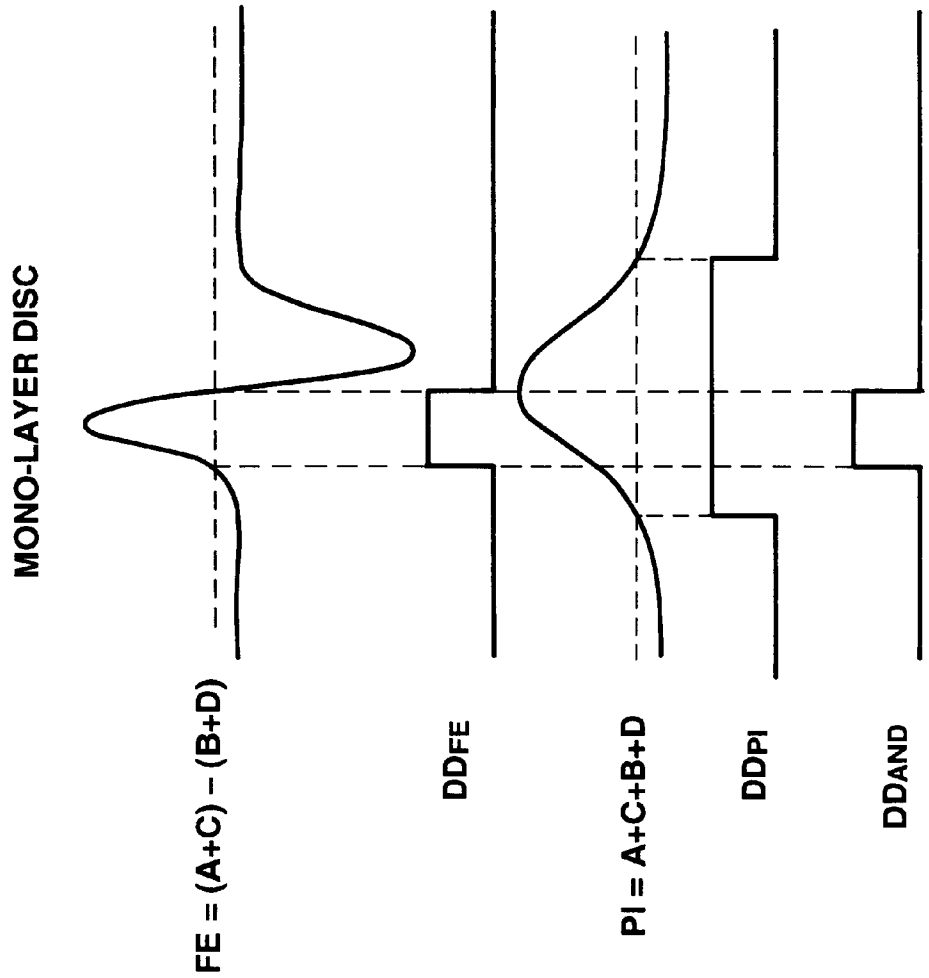


FIG.19A

FIG.19B

FIG.19C

FIG.19D

FIG.19E

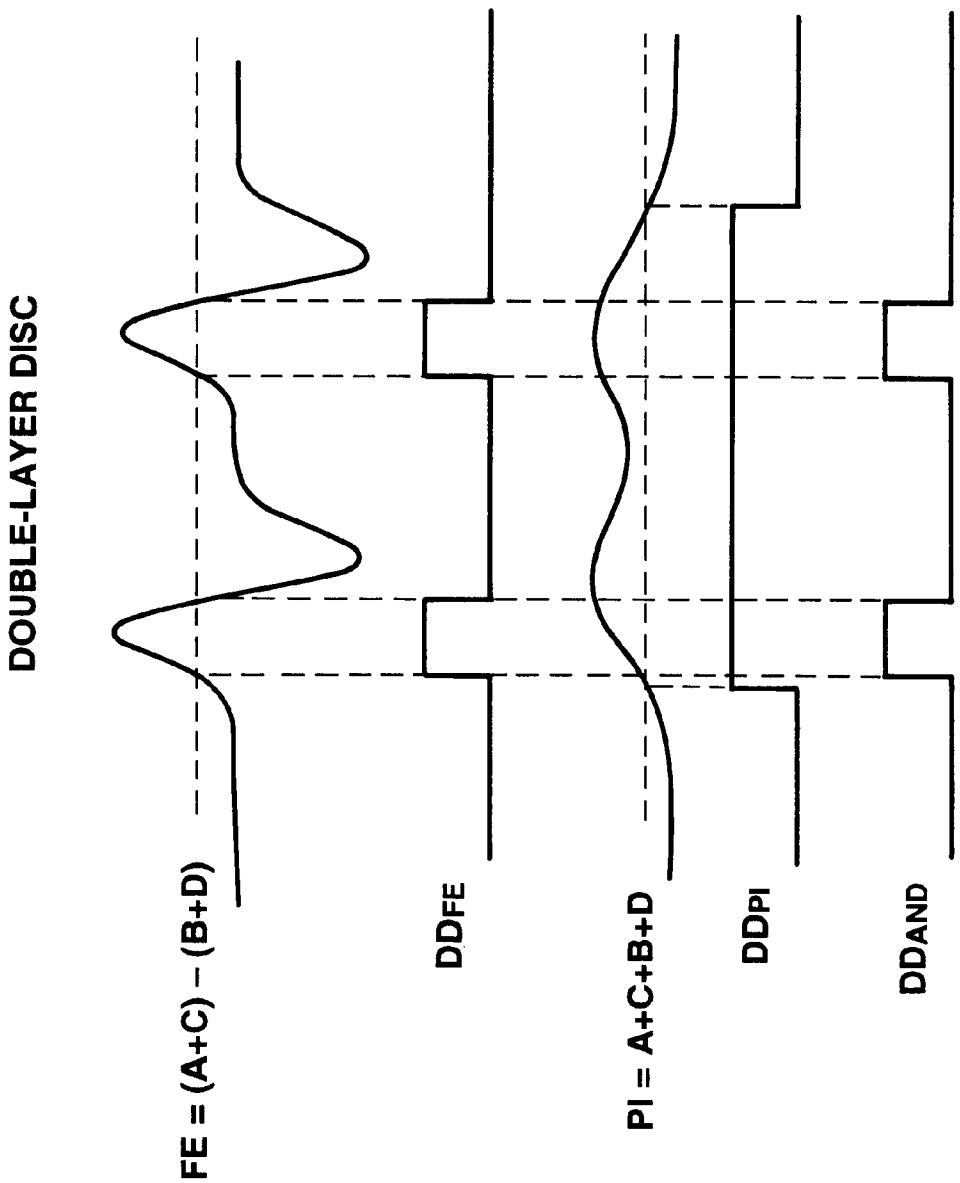


FIG.20A FIG.20B FIG.20C FIG.20D FIG.20E

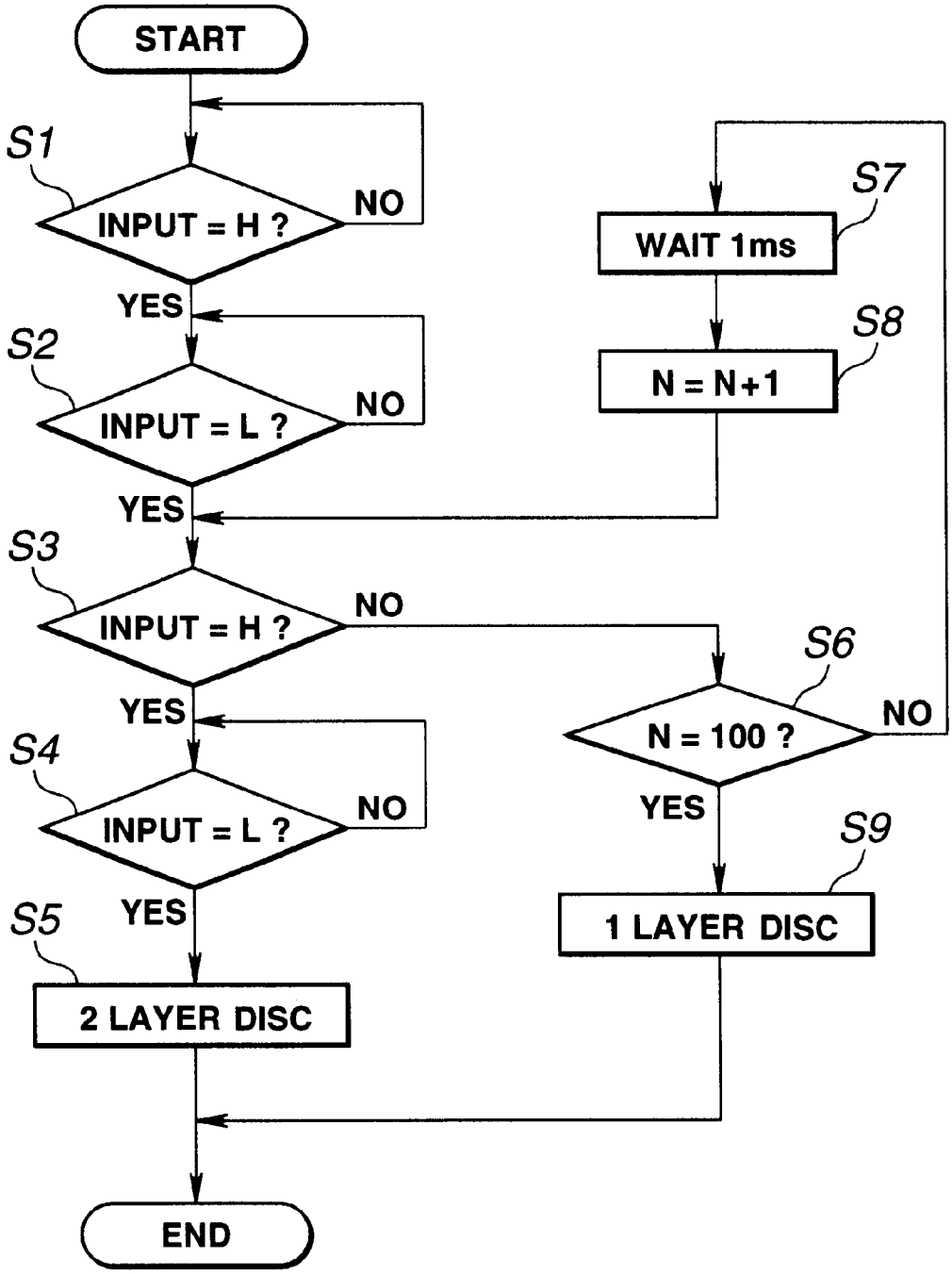

START
S1
INPUT = H ?
NO
YES
S2
INPUT = L ?
NO
YES
S3
INPUT = H ?
NO
YES
S4
INPUT = L ?
NO
YES
S5
2 LAYER DISC
S7
WAIT 1ms
S8
N = N+1
S6
N = 100 ?
NO
YES
S9
1 LAYER DISC
END

FIG.21

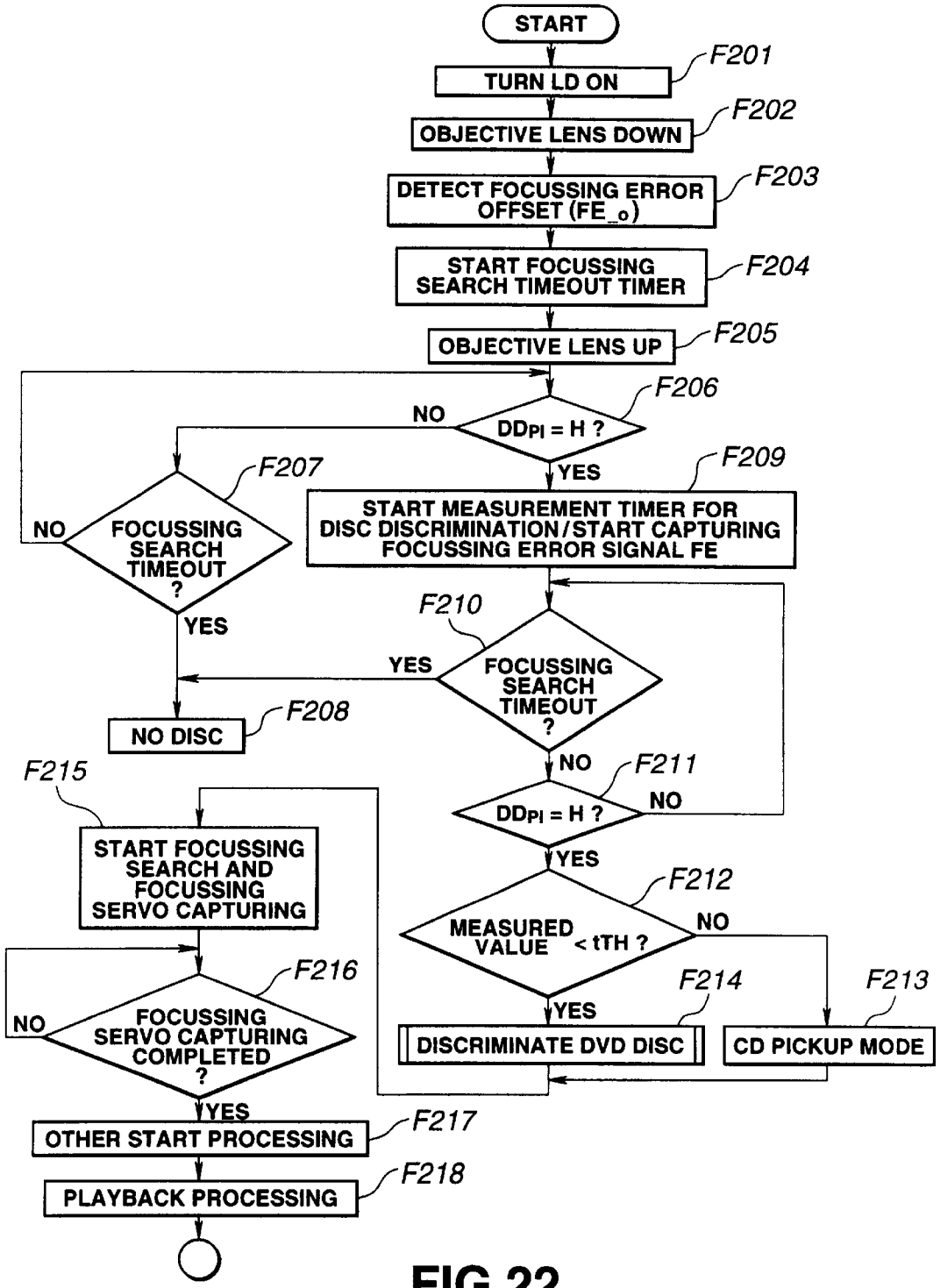

START
F201
TURN LD ON
F202
OBJECTIVE LENS DOWN
F203
DETECT FOCUSSING ERROR OFFSET (FE_o)
F204
START FOCUSSING SEARCH TIMEOUT TIMER
F205
OBJECTIVE LENS UP
F206
NO
DDPI = H ?
YES
F207
NO
FOCUSSING SEARCH TIMEOUT ?
YES
F209
START MEASUREMENT TIMER FOR DISC DISCRIMINATION/START CAPTURING FOCUSSING ERROR SIGNAL FE
F210
YES
FOCUSSING SEARCH TIMEOUT ?
F208
NO DISC
NO
F211
DDPI = H ?
NO
YES
F212
MEASURED VALUE < tTH ?
NO
YES
F214
DISCRIMINATE DVD DISC
F213
CD PICKUP MODE
F215
START FOCUSSING SEARCH AND FOCUSSING SERVO CAPTURING
F216
NO
FOCUSSING SERVO CAPTURING COMPLETED ?
YES
F217
OTHER START PROCESSING
F218
PLAYBACK PROCESSING

FIG.22

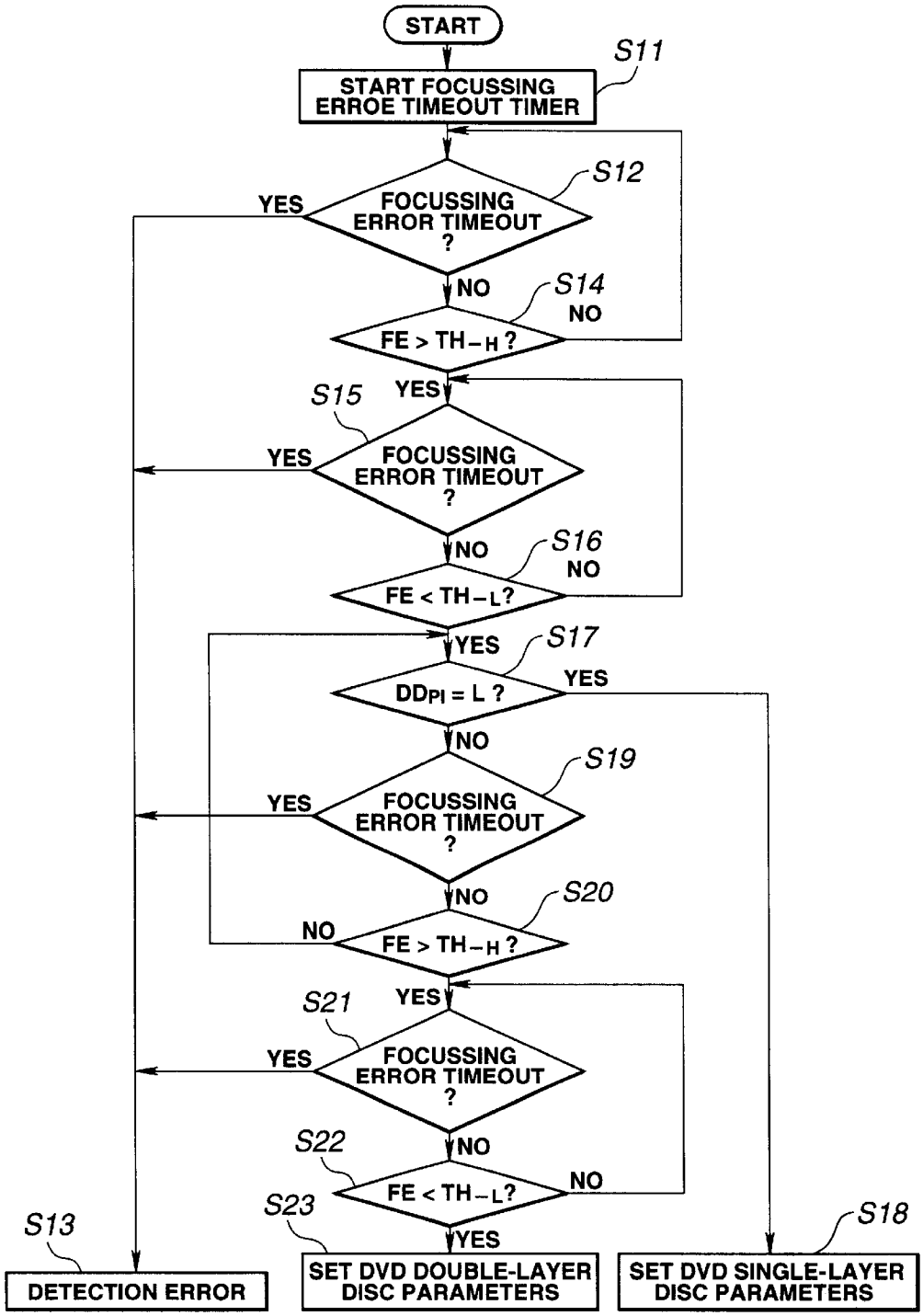
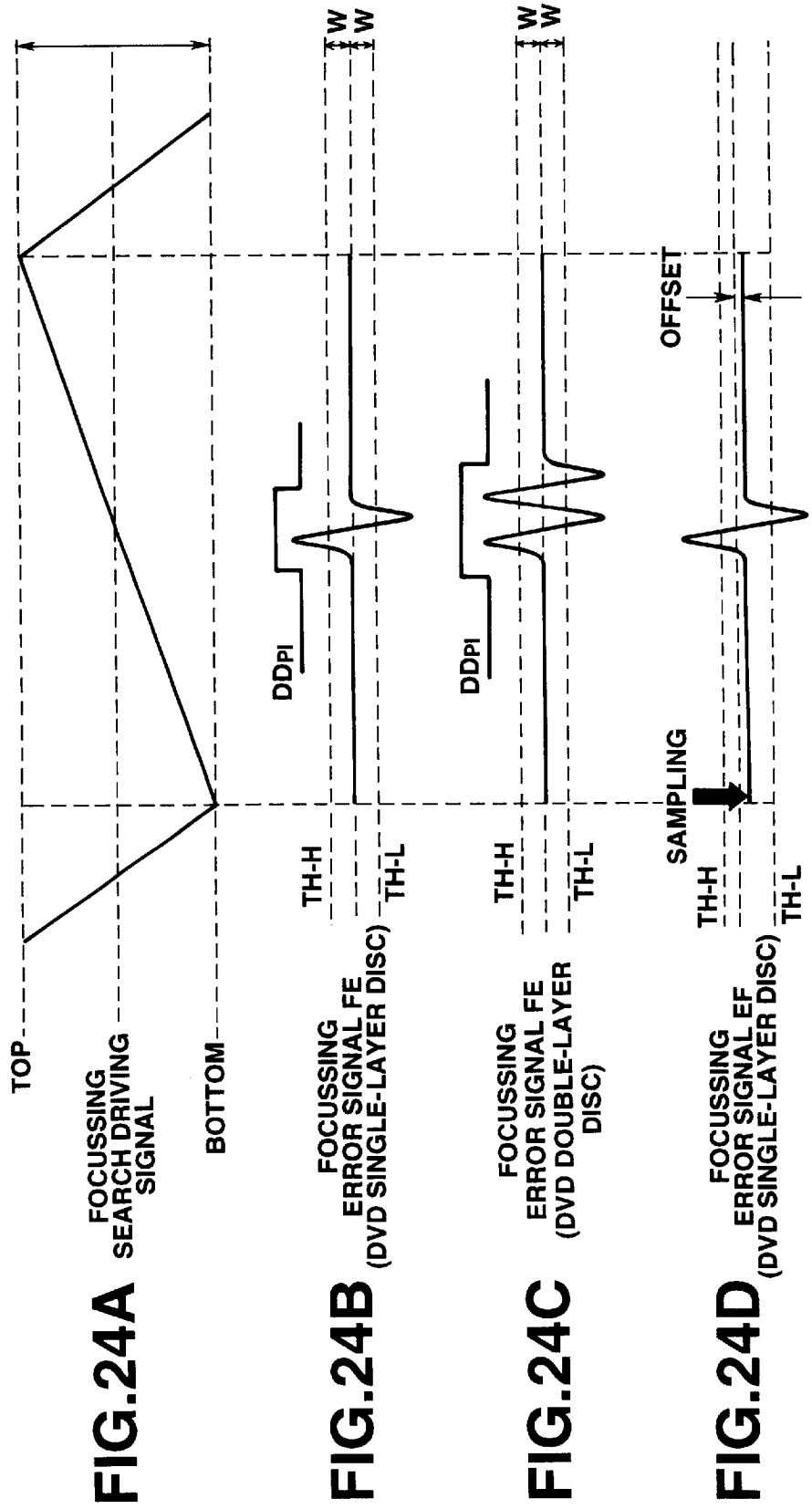

START
S11
START FOCUSSING ERROE TIMEOUT TIMER
S12
YES
FOCUSSING ERROR TIMEOUT ?
NO
S14
NO
FE > TH−H ?
YES
S15
YES
FOCUSSING ERROR TIMEOUT ?
NO
S16
NO
FE < TH−L?
YES
S17
DDPI = L ?
YES
NO
S19
YES
FOCUSSING ERROR TIMEOUT ?
NO
S20
NO
FE > TH−H ?
YES
S21
YES
FOCUSSING ERROR TIMEOUT ?
NO
S22
FE < TH−L?
NO
S23
YES
S13
DETECTION ERROR
SET DVD DOUBLE-LAYER DISC PARAMETERS
S18
SET DVD SINGLE-LAYER DISC PARAMETERS

FIG.23


TOP
BOTTOM
FOCUSSING SEARCH DRIVING SIGNAL
FIG.24A
DDPI
W
W
TH-H
TH-L
FOCUSSING ERROR SIGNAL FE (DVD SINGLE-LAYER DISC)
FIG.24B
DDPI
W
W
TH-H
TH-L
FOCUSSING ERROR SIGNAL FE (DVD DOUBLE-LAYER DISC)
FIG.24C
OFFSET
SAMPLING
TH-H
TH-L
FOCUSSING ERROR SIGNAL EF (DVD SINGLE-LAYER DISC)
FIG.24D

OPTICAL DISC DEVICE AND OPTICAL DISC DISCRIMINATING METHOD

This application is a continuation of international application number PCT/JP/98/000111, filed Jan. 6, 1998, now pending.

1. Technical Field

This invention relates to an optical disc device capable of coping with plural types of optical discs, and a method for discriminating optical discs.

2. Background Art

As optical discs, compact discs are in widespread use, such that optical discs of the CD type are used in many fields, to say nothing of the field of musical application. The CDs for music are usually designed as replay-only media. However, an overwrite type disc termed compact disc recordable (CD-R) is also commercialized.

On the other hand, an optical disc termed a digital versatile disc/digital video disc (DVD) has also been developed as an optical disc suitable for multimedia use. This DVD is proposed as being adaptable to a wide field of applications, such as for video data, audio data or computer data. The DVD, which is an optical disc of the same size as the CD (12 cm in diameter), has a significantly increased recording capacity.

Meanwhile, in keeping pace with development of a new optical disc, it becomes desirable to provide an optical disc device exhibiting interchangeability between conventional and newer types of optical discs.

As for the DVD, it is desirable to develop an optical disc device capable of coping with both the CD and the DVD. However, since the CD and the DVD differ in reflectivity depending on, for example, the difference in structure of the signal recording layer of the optical disc, the RF signals obtained by an optical pickup is varied in signal level, depending on the optical disc type, whilst optimum values of parameters of various servo systems, such as focussing servo or tracking servo systems, are also changed.

Therefore, an optical disc device, adapted for coping with plural optical disc types, is required to correctly discriminate the type of optical disc on loading the optical disc thereon.

If the disc is of the type in which an optical disc is housed in a cartridge, the disc type can be easily discriminated by providing a cartridge discriminating hole. However, if the optical disc is not of the type housed in a cartridge, and moreover the optical disc itself is of the same size, this mechanical discrimination system cannot be used.

Moreover, if special components or units are provided for discriminating the disc type, such as a sensor, the device is undesirably complicated in structure, while the manufacturing costs are also raised.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an optical disc device and an optical disc discriminating method in which plural optical disc types having different numbers of signal recording layers are discriminated and an operating mode corresponding to the optical disc type is set by control means based on the discriminating output for reliably reproducing the plural types of optical discs.

In one aspect, the present invention provides an optical disc device including a laser light source for radiating a laser light beam illuminated on a signal surface of an optical disc via an objective lens, photodetector means for detecting the light of the laser light radiated by the laser light source and reflected from the signal surface of the optical disc, focussing control means for displacing the objective lens responsive to the focussing error signals generated on the basis of a detection output by the photodetector means for controlling the focussing state of the beam spot of the laser light bam on the signal surface, disc discrimination means for discriminating the types of the optical discs, based on the focussing error signals, when the objective lens is moved by the focussing control means along the optical axis for focussing search and control means for setting an operating mode in meeting with the disc types based on a discrimination output by the disc discrimination means.

With the optical disc device of the present invention, photodetector means has a photodetector split in at least four segments. The focussing control means performs focussing control, based on a focussing error signal FE=(A+B)−(C+D) in which A, B, C and D denote detection signals of the four segments of the photodetector. The disc discrimination means generates a gating pulse by converting a sum signal PI=A+B+C+D of the detection signals A to D of the photodetector at a pre-set level into binary-valued signals at a pre-set level. The disc discrimination means converts the focussing error signals FE into binary-valued signals for generating discriminating pulses. The disc discrimination means counts the discriminating pulses for discriminating the disc types having different numbers of recording layers based on the counted results.

In the optical disc device of the present invention, the disc discrimination means sets a threshold level for the above conversion-to-binary operation responsive to, for example, the window width proper to the gate pulse.

Also, in the optical disc device of the present invention, the disc discrimination means detects the distance between the optical disc surface and the signal surface based on a detection output of the photodetector means to discriminate plural optical discs having different substrate thicknesses based on this detected distance.

Also, in the optical disc device of the present invention, the disc discrimination means discriminates the types of the optical discs based on an output timing of the photodetector means during the time of outputting of focussing search signals for shifting the objective lens along the optical axis.

Also, in the optical disc device of the present invention, the disc discrimination means detects whether an optical disc to be discriminated is a one-layer disc having a sole signal surface or a double-layer disc having two signal surfaces, based on, for example, the above focussing error signals.

Also, in the optical disc device of the present invention, the disc discrimination means detects the types of plural discs with different numbers of the signal recording layers based on the focussing error signals detected during the time the focussing control means shifts the objective lens in a direction approaching to the optical disc.

Also, in the optical disc device of the present invention, the disc discrimination means detects whether the optical disc to be discriminated is a first optical disc having a first thickness or a second optical disc having a second thickness smaller than said first thickness based on a detection output by said photodetector means.

The optical disc device of the present invention includes convert-to-binary means for converting the focussing error signals to binary signals by comparing the signal level of the focussing error signals to pre-set positive and negative levels and detects the type of the optical disc by checking the number of times of occurrences of the binary focussing error signals.

The present invention also provides an optical disc device in which a laser light beam is radiated via an objective lens so as to be illuminated on a signal surface of the optical disc to reproduce signals recorded on the signal surface, including focussing control means for shifting the objective lens from a first position remote from the optical disc to a second position approaching to the optical disc and disc discrimination means for discriminating whether the optical disc is a single-plate disc or a laminated disc based on the reflected light from the disc surface and the reflected light from the signal recording surface detected during the time interval when the objective lens is moving from the first position to the second position and disc discrimination means for discriminating whether the disc is the single-layer disc or a double-layer disc based on the focussing error signals detected during said time interval.

In another aspect, the present invention provides a method for discriminating an optical disc including a generating step of illuminating a laser light beam on a signal surface of the optical disc via an objective lens, a generating step of detecting the reflected light of the laser light from the signal surface of the optical disc as the optical disc is displaced along the optical axis for generating a focussing error signal from a detected output, and a discriminating step of discriminating the disc types having different numbers of the signal recording layers, including the signal surface, based on the generated focussing error signal.

With the optical disc discriminating method of the present invention, the reflected laser light is detected in the generating step by a photodetector split into at least four segments. The discriminating step includes a sub-step of converting a focussing error signal FE=(A+B)−(C+D) obtained from detection signals A, B, C and D of the four-segment photodetector into binary-valued signals for generating a discriminating pulse and converting a sum signal PI=A+B+C+D of the detection signals A to D of the photodetector at a pre-set level into binary-valued signals for generating gating pulses and a sub-step of counting the discriminating pulses during the gating period supplied by the gating pulse for discriminating the disc types of different numbers of recording layers based on the counted results.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A, **1**B, and **1**C illustrate the structure of an optical disc associated with an optical disc device embodying the invention.

FIG. **2** is a perspective view showing a mechanical deck of the optical disc device.

FIG. **3** is a block diagram showing the structure of the optical disc device.

FIG. **4** is a schematic plan view of an eight-segment photodetector of the optical disc device.

FIG. **5** is a block diagram showing the structure of a tracking block in the optical disc device.

FIGS. **6**A and **6**B illustrate the physical structure of a DVD-RW disc associated with the optical disc device.

FIG. **7** is a block diagram showing the structure of a third tracking error signal generating block in the tracking block.

FIG. **8** is a circuit diagram showing the structure of a DPD filter in the third tracking error signal generating block in the tracking block.

FIG. **9** is a graph showing the frequency response of the DPD filter.

FIG. **10** is a block diagram showing the structure of a mirror block in the optical disc device.

FIGS. **11**A, **11**B, **11**C, and **11**D are waveform diagrams for illustrating the operation of the mirror block.

FIG. **12** is a block diagram showing the structure of a discrimination signal generating block in the optical disc device.

FIG. **13** is a circuit diagram showing the structure of an APC circuit in the optical disc device.

FIG. **14** is a graph showing gain characteristics of the APC circuit.

FIGS. **15**A, **15**B, **15**C, and **15**D show the relative position between a CD and an objective lens for illustrating the operating principle of disc discrimination in the optical disc device.

FIGS. **16**A, **16**B, **16**C, and **16**D show the relative position between a DVD and an objective lens for illustrating the operating principle of disc discrimination.

FIGS. **17**A, **17**B, **17**C, **17**D, and **17**E are waveform diagrams of various signals for illustrating the operating principle of disc discrimination.

FIG. **18** is a flowchart for illustrating the operation of disc discrimination.

FIGS. **19**A, **19**B, **19**C, **19**D, and **19**E are waveform diagrams showing a disc discrimination signal for a single-layer disc.

FIGS. **20**A, **20**B, **20**C, **20**D, and **20**E are waveform diagrams showing a disc discrimination signal for a double-layer disc.

FIG. **21** is a flowchart for illustrating the sequence of operations for discriminating the single-layer disc and the double-layer disc by a system controller in the optical disc device.

FIG. **22** is a flowchart for illustrating another example of the operations for discriminating the disc types by a system controller in the optical disc device.

FIG. **23** is a flowchart for illustrating the sequence of operations for discriminating the single-layer disc and the double-layer disc in the example of the operations for discriminating the disc types by the system controller.

FIGS. **24**A, **24**B, **24**C, and **24**D are waveform diagrams for illustrating the disc discrimination signal in the sequence of operations for discriminating the single-layer disc and the double-layer disc.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to the drawings, preferred embodiments for carrying out the present invention will be explained in detail.

The present invention is applied to an optical disc device associated with a CD and a DVD. Before proceeding to the explanation of the optical disc device embodying the invention, the structures of the CD, CD-R and the DVD will be explained with reference to FIG. **1**. Meanwhile, the CD, CD-R and the DVD are all discs 12 cm in diameter.

FIGS. **1**A, **1**B and **1**C illustrate a layered structure as cross-sections of the CD, CD-R and the DVD. As shown in these figures, the overall disc thickness of each of the CD, CD-R and the DVD is approximately 1.2 mm.

On the CD **100** shown in FIG. **1**A, a disc substrate (transparent layer) **101** is molded from a transparent synthetic resin material, such as a transparent polycarbonate resin, polyvinyl chloride or acrylic resin, having high light transmission, mechanical resistance and resistance against chemicals. On a major surface of the disc substrate **101** are transcribed pits by a stamper assembled into a mold die.

These pits in the signal surface **102** are formed in the disc substrate **101** as encoded orifices having different circumferential lengths in association with pre-set information signals for constituting a recording track. On the surface of the disc substrate **101** carrying the signal surface **102** is deposited aluminum having high light reflectance for forming a reflective layer **103** as a signal recording layer. The entire assembly is covered by a protective layer **104** for completing a CD **100**.

On this CD **100**, a laser light beam from the disc driving device falls from the disc surface **105** so that the information recorded on the signal surface **102** is detected from the reflected laser light.

FIG. **1**B shows a CD-R **110** which is a medium permitting the overwriting. The CD-R **110** has the physical properties, such as diameter, weight and thickness, in common with the CD **100**. However, the CD-R **110** can be manufactured economically in smaller quantities and longer in durability than the CD **100** and hence is suited for data storage.

On this CD-R **110** is also arranged a disc substrate (transparent layer) **111** looking from the disc surface **116**. On the disc substrate **111** are layered an organic dye layer **114**, as a signal recording layer, a gold reflective layer **113** as a protective layer **115**, in this order, for completing the CD-R **110**. In this CD-R **110** is also formed a groove operating as laser light illumination guide during recording and which is covered by the organic dye layer **114**. The organic dye layer **114** is reacted with polycarbonate of the disc substrate **111**, under the heat of the illuminated laser light, for forming the pits corresponding to the information signals on the groove for forming a signal surface **112** carrying actual data.

Similarly, a DVD **120** shown in FIG. **1**C has a disc substrate **121**, from a disc surface **128**, and a signal surface on the opposite side with respect to the disc substrate **121**. Two types of the DVD, that is a DVD with a single signal surface, termed a single-layer disc, and a DVD with a double signal surface, termed a double-layer disc. FIG. **1**C shows an example of the double-layer disc. That is, a first data recording layer is formed by a first signal surface **122** and a first reflective layer **123** associated with the first signal surface **122**. A second data recording layer is formed by a second signal surface **124** and a second reflective layer **125** associated with the second signal surface **124**. An adhesive surface **126** is formed on the second reflective layer **125** and a dummy substrate **127** is bonded by this adhesive surface **126**.

The first reflective layer **123** is a semi-transparent film and is designed to reflect a pre-set proportion of the laser light. Thus, if the laser light is focussed on the first signal surface **122**, the signals recorded on the first signal surface **122** can be read from the reflected light by the first reflective layer **123**, whereas, if the laser light is focussed on the second signal surface **124**, the laser light is transmitted through the first reflective layer **123** to be converged on the second signal surface **124**, such that the signals recorded thereon can be read out from the light reflected by the second reflective layer **125**.

In case of the single-layer disc, the signal surface and the reflective layer are formed similarly to the second signal surface **124** and the second reflective layer **125**, respectively.

As may be seen from FIGS. **1**A, **1**B and **1**C, the signal surfaces **102** and **112** of the CD **100** and the CD-R **110** are formed at separations close to the disc thickness from the disc surfaces **105**, **116**. That is, the signal surfaces **102** and **112**, on which to focus the laser spot, are separated approximately 1.2 mm from the disc surfaces **105**, **116**.

On the other hand, the signal surfaces **122** (**124**) of the DVD **120** are at a mid point of the disc thickness. That is, the signal surfaces **122** and **124**, on which to focus the laser spot, are separated approximately 0.6 mm from the disc surface **128**. The recording density by pits formed on the signal surfaces **122** (**124**) is higher than that of the CD **100** and the CD-R **110**.

Due to this difference, laser light having a wavelength not larger than 650 nm is used as the playback laser light. In addition, the numerical aperture (NA) of the objective lens is increased to 0.6, while the optical pickup used is optimized for focussing the laser spot at a position separated approximately 0.6 mm from the disc surface **128**.

Meanwhile, in a CD/DVD compatible device, it is not impossible to read out the information on the signal surface **102** of the CD **100** by laser light having a wavelength not larger than 650 nm. It is also not impossible to focus the laser spot at a separation approximately 1.2 mm from the disc surface **105** of the CD **100**. It is however best to use an optical pickup device having its various characteristics optimized for the CD **100** in view of playback characteristics.

The CD-R **110** also has an organic dye layer **114** which has a dependence on wavelength, such that, if laser light having a wavelength not larger than 650 nm is used, data cannot be reproduced correctly. That is, with the CD-R **110**, light absorption of the illuminated laser light of not larger than 650 nm by the organic dye layer **114** is increased to lower the reflectivity. In addition, the modulation factor of the laser light by the pits on the signal surface **112** is lowered. When recording data, pits are formed with the absorptivity and reflectance suited to laser light of wavelength 780 nm, it is not possible to obtain a sufficient modulation factor even if attempts are made to read out the pits by the laser light of other wavelengths.

It is thus desirable to use at least an objective lens and a laser light source dedicated to each optical disc type for an optical disc device which is compatible for the CD **100** (CD-R **110**) and the DVD **120**.

Thus, the optical disc device of the invention, as now explained, has an optical pickup **1***a*, dedicated to the CD **100** and the CD-R **110**, and an optical pickup **1***a*, dedicated to the DVD **120**. The CD **100**, CD-R **110** and the DVD **120**are collectively termed an optical disc D.

FIG. **2** shows a perspective view of a playback driving portion (a so-called mechanical deck portion) of the optical disc in the optical disc device.

This mechanical deck includes, on a main body portion of a sub-chassis **11**, a variety of units required for reproducing the optical disc. The loaded optical disc D is mounted on a turntable **7** which is driven by a spindle motor **6** for rotating the optical disc.

The optical pickup **1**, illuminating the laser light on the rotating optical disc for extracting the information from the reflected light, includes, within its shell, a CD pickup **1***a*, having an optical system and a laser light source, optimized for the CD **100** (CD-R **110**), and a DVD pickup **1***b*, having an optical system and a laser light source, optimized for the DVD. These pickups **1***a*, **1***b* are provided independently of each other. A laser output end of the CD pickup **1***a* is an objective lens for CD **2***a*, while a laser output end of the DVD pickup **1***b* is an objective lens for DVD **2***b*.

The optical pickup **1** is slidable along the disc radius by a so-called sled mechanism. To this end, a main shaft **8***a* and a sub-shaft **12** are provided on both sides of the optical pickup **1**. The main shaft **8***a* is passed through a holder **8***g* of the optical pickup **1**, while the sub-shaft **12** is passed

through an opposite side holder portion, not shown, so that the optical pickup **1** is movable along the shaft length as the optical pickup **1** is supported by the main shaft **8***a* and the sub-shaft **12**.

As a mechanism for moving the optical pickup **1**, a sled motor **8***b*, and sled transmitting gears **8***c*, **8***d* and **8***e* are provided, while a rack gear **8***f* is mounted in the vicinity of the holder portion **8***g* of the optical pickup **1**.

When the sled motor **8***b* is run in rotation, its rotational power is transmitted to the sled transmitting gears **8***c*, **8***d*, **8***e* in this order. Since the thread transmitting gear **8***e* meshes with the rack gear **8***f*, the transmitted rotational power causes the optical pickup **1** to be moved along the shaft. Thus, the optical pickup **1** is moved towards the inner and outer disc rim portions by rotation of the sled motor **8***b* in the forward and reverse directions.

FIG. **3** is a block diagram showing essential portions of the optical disc driving device.

The optical disc D is loaded on the turntable **7**, also shown in FIG. **2**, and is run in rotation by spindle motor **6** at CLV or CAV during the playback operation.

By the optical pickup **1**, data recorded as pits on the optical disc D are read out. In actuality, two independent optical pickups, that is the CD pickup **1***a* and the DVD pickup **1***b*, are provided as the optical pickup **1**, as discussed previously.

The CD pickup **1***a* is provided with an optical system suited to the CD **100** and the CD-R **110**. A laser diode **4***a*, operating as a laser light source, has a center output wavelength of 780 nm, with the objective lens for CD **2***a* having NA=0.45. The objective lens for CD **2***a* is held by a biaxial mechanism **3***a* for movement in the tracking direction and in the focussing direction.

The optical pickup for DVD **1***b* has an optical system optimum for the DVD **120**. A laser diode **4***b*, operating as a laser light source, has a center output wavelength of 650 nm or 635 nm, with the objective lens for DVD **2***b* having NA=0.6. The objective lens for DVD **2***b* is held by a biaxial mechanism **3***b* for movement in the tracking direction and in the focussing direction.

If the optical disc D is the CD **100**, the playback operation is performed by the pickup for CD **1***a*. The reflected light information from the optical disc D is detected by a photodetector **5***a* and converted into electrical signals corresponding to the received light volume so as to be supplied to a RF block **21**.

If the optical disc D is the DVD **120**, the playback operation is performed by the pickup for DVD **1***b*. In this case, the reflected light information from the optical disc D is detected by a photodetector **5***b* and converted into electrical signals corresponding to the received light volume so as to be supplied to the RF block **21**.

The CD pickup and the DVD pickup **1***b* are provided respectively, as the photodetectors **5***a*, **5***b*, with a eight-segment photodetector, made up of four-segment detectors S_A, S_B, S_C and S_D, on either side of which two-segment detectors S_E, S_F and two-segment detectors S_G, S_H are provided, as shown in FIG. **4**.

The RF block **21** includes a current-voltage conversion circuit, an amplifier circuit and a matrix calculation circuit and generates necessary signals based on signals from the photodetectors **5***a*, **5***b*. For example, the RF block **21** generates RF signals. As playback signals, focussing error signals FE and tracking servo signals TE for servo control, pull-in signals PI, as so-called sum signals, and disc discrimination signals DD_{PI}, DD_{AND} and $DD_{A/D}$.

From detection signals A, B, C and D by the detectors S_A, S_B S_C and S_D of the eight-segment photodetector, the RF block **21** generates the focussing error signals FE and the pull-in signal PI by the following equations:

$$FE=(A+C)-(B+D)$$

$$PI=A+C+B+D$$

For generating the tracking error signals TE, the RF block **21** has a tracking block **40** configured as shown in FIG. **5**.

The tracking block is a block for generating tracking error signals TE from the detection signals A to H of the eight-segment photodetector, and has three tracking error signal generating blocks **41**, **42** and **43** for generating three tracking error signals **3**SP, DPP and DPD, as shown in FIG. **5**. The tracking block selects the three tracking error signals **3**SP, DPP or DPD by a changeover switch **44** to output the selected signal via an output unit **45**. The changeover switch **44** is a four-input switch and is adapted for selecting an external input signal AUX. The changeover switch **44** is switching-controlled, depending on the type of the optical disc D. The above-mentioned system controller **30** is adapted for discriminating the type of the optical disc D based on the disc discrimination signals DD_{PI}, DD_{AND} and $DD_{A/D}$.

Specifically, the system controller **30** discriminates between the CD **100** (CD-R **110**) and the DVD **120**, having different disc substrate thicknesses, based on the disc discrimination signal DD_{PI}, while discriminating between the DVD **120** and a DVD-RW **130**, as later explained, by different reflectivities, based on the disc discrimination signal $DD_{A/D}$. If, as a result of discrimination, the optical disc D loaded on the turntable **7** is the CD **100** or the CD-R **110**, the system controller **30** switching-controls the changeover switch **44** such as to output tracking error signals **3**SP. If the disc D is the DVD **120**, the system controller **30** switching-controls the changeover switch **44** such as to output tracking error signals DPD, whereas, if the disc D is the DVD-RW **130**, the system controller **30** switching-controls the changeover switch **44** such as to output tracking error signals DPP.

In the tracking block **40**, the first tracking error signal generating block **41** generates three-spot type tracking error signals **3**SP in accordance with the equation:

$$3SP=(E+F)-(G+H)$$

That is, the first tracking error signal generating block **41** generates a difference signal between a sum signal of detection signals E and F of detectors S_E and S_F and a sum signal of detection signals G and H of detectors S_G and S_H. The detectors S_E and S_F and the detectors S_G and S_H are arranged on both sides of the detectors S_A to S_D, arranged at the center of the eight-segment photodetector, **5***a*, **5***b* as discussed previously.

The present system is a generic detection system for detecting tracking errors during reproduction of a laser beam spot for the recording track generated on the signal surface of the optical disc having a thickness of approximately 1.2 mm, that is the CD **100** or the CD-R **110**.

On the other hand, the second tracking error signal generating block **42** generates tracking error signals DPP of the differential push-pull system in accordance with the equation:

$$DPP=\{(A+D)-(B+C)\}-\{(F+H)-(E+G)\}$$

The present system is a detection system used for recording/reproducing an optical disc DVD-RW

(Rewritable) which is a rewritable recording medium, now being researched, pursuant to the DVD standard. The physical structure of the DVD-RW **130** is hereinafter explained with reference to FIGS. **6**A and **6**B.

Similarly to the DVD **120**, the DVD-RW **130** has a signal surface formed at a spacing of approximately 0.6 mm from the disc surface. In a recordable area of the instant embodiment of the DVD-RW **130** is pre-formed a tracking pre-grove **132** extending spirally from the inner rim to the outer rim, as shown in FIG. **6**A.

This pre-groove **132** is formed on a disc substrate **131**, and has its left and right sidewall portions meandering at a pre-set period in meeting with the address information, as shown in FIG. **6**B showing part of the pre-groove on an enlarged scale. That is, the pre-groove **132** is meandering at a pre-set period corresponding to wobbling signals generated on the basis of the addresses. The area confined between neighboring pre-grooves **132** is a land **133**. The surface of the disc substrate **131** formed with the pre-groove **132** and the land **133** is coated with a phase-transition recording film, as a recording layer, having its reflectivity changed depending on the crystallized state. Data are recorded on the pre-groove **132** as the recording track.

In recording/reproducing the data on or from the DVD-RW **130**, the DVD pickup **1***b* generates three light beams by a diffraction lattice and arrays both side beam spots on the recording surface of the optical disc with an offset of one-half the track pitch along the disc radius relative to the mean beam spot. The reflected light of the main beam is detected by the split detectors S_A, S_B, S_C and S_D of the eight-segment photodetector shown in FIG. **4** so as to be output as detection signals A to D. On the other hand, the reflected light of the side beams is detected by the split detectors S_E, S_F and the split detectors S_G and S_H so as to be output as detection signals E to H. The above-mentioned calculations are executed on the detection signals A to H detected by the detectors S_A to S_H for producing the tracking error signals DPP of the differential push-pull system. The tracking error signals DPP are freed of offset components applied by objective lens movement on tracking error signals of the conventional push-pull system.

In addition, the third tracking error signal generating block **43** is configured as shown in FIG. **7** for generating the tracking error signal DPD of the differential phase detection (DPD) system from the detection signals A, B, C and D of the detection signals A to H of the eight-segment photodetector.

The present system is tracking error detection system for an optical disc, such as an optical disc having a thickness of approximately 0.6 mm, higher in recording density than the CD **100**.

That is, the third tracking error signal generating block **43** includes DPD filters **46**A, **46**B, **46**C and **46**D, supplied with the detection signals A to D of the detection signals A to H of the eight-segment photodetector detected by the four central detectors S_A, S_B, S_C and S_D of the photodetector detecting the reflected light of the main beam, and level comparators **47**A, **47**B, **47**C and **47**D supplied with the detection signals A to C bandwidth-limited by the DPD filters **46**A to **46**D, respectively. The third tracking error signal generating block **43** also includes phase comparators **48**A, **48**B supplied with output signals of the level comparators **47**A, **47**B, **47**C and **47**D and an integration circuit **49** supplied with output signals of the phase comparators **48**A, **48**B.

In the third tracking error signal generating block **43**, the level comparators **47**A, **47**B, **47**C and **47**D compare the detection signals A to D, entered via DPD filters **46**A, **46**B, **46**C and **46**D, to a pre-set level VC, for converting the detection signals A to D to binary-valued signals. The phase comparators **48**A, **48**B phase-compare the binary-valued detection signals A to D. The maximum operating frequency of the phase comparators **48**A, **48**B is 10 MHZ. The integrating circuit **49** integrates the output signals of the phase comparators **48**A, **48**Bwith 30 kHz for outputting the tracking error signals DVD.

The DPD filters **46**A, **46**B, **46**C and **46**D of input units of the third tracking error signal generating block **43** are each made up of a high-pass filter HPF**1** for cutting dc components, two band-pass filters BPF**1**, BPF**2** for amplifying EFM+ signal components and an output selection switch SW_{DPD} for selecting the band-pass filters BPF**1**, BPF**2**. The frequency response can be changed over by selecting one of the two band-pass filters BPF**1**, BPF**2** by the output selection switch SW_{DPD}, as shown in FIG. **9**.

The output selection switch SW_{DPD} is switching-controlled, depending on the type of the optical disc **30**, by the above system controller **30** which discriminates the type of the optical disc D based on the above disc discrimination signals DD_{PI}, DD_{AND} and $DD_{A/D}$.

That is, the system controller **30** discriminates between the CD **100** and the DVD **120**, by the disc discrimination signals DD_{PI}, as later explained, and changes over the output selection switch SW_{DPD} for selecting the band-pass filter BPF**2** having a passband on a higher side tan the band-pass filter SPF**1** if the disc is the DVD **120**.

The RF block **21** generates a mirror signal MIRR by a mirror block **50** configured as shown in FIG. **10**.

This mirror block **50** includes a low-pass filter **51**, provides at an input unit supplied with a RF signal RF_AC, obtained as a detection signal by the photodetectors **5***a*, **5***b*, and an amplifier circuit **52** supplied with an output signal LPF_{OUT} of the low-pass filter **51**. The mirror block **50** also includes a peak-holding circuit **53** and a bottom-holding circuit **54**, supplied with an output signal AM_{OUT} of the amplifier circuit **52**. The mirror block **50** also includes a reference level signal generating circuit **55** supplied with output signals PKH_{OUT} and BMH_{OUT} of the peak-holding circuit **53** and the bottom-holding circuit **54**. The mirror block **50** further includes a level comparator circuit **56** supplied with a reference level signal REF from the reference level signal generating circuit **55**.

In this mirror block **50**, the low-pass filter **51** is used for extracting a traversing signal from the RF_AC shown in FIG. **11**A and has its cut-off frequency changed over between 60 kHz and 30 kHz by a switch SWLPF which is switching-controlled by the system controller **30** depending on the type of the optical disc D.

That is, the system controller **30** discriminates the type of the optical disc D, by the method as later explained, based on the disc discrimination signals DD_{PI}, for changing over the switch SWLPF to 60 kHz or to 30 kHz for the DVD **120** and for the CD **100**, respectively.

On the other hand, the amplifier circuit **52** is used for amplifying the output signal LPF_{OUT} of the low-pass filter **51**, that is the traversing signal, and has its gain changed over between 12 dB and 2 dB by the switch SWAMP, which is switching-controlled by the system controller **30** depending on the type of the optical disc D.

This switching is done for coping with recently developed rewritable optical discs CD-RW or DVD-RW, employing a phase transition recording film. Specifically, the reflectivity of the optical disc is detected by the disc discrimination signals $DD_{A/D}$ and the switch SWAMP is changed over to

raise the gain to 12 dB for reproducing the disc having a reflectivity of ¼ to ⅕ of the reflectivity of the CD **100**.

Further, the peak-holding circuit **53** holds the peak level of the output signal AM_{OUT} of the amplifier circuit **52** and feeds the output signal PKH_{OUT} to the reference level signal generating circuit **55**. Also, the bottom-holding circuit **54** holds the bottom level of the output signal AMP_{OUT} and feeds the output signal BMH_{out} to the circuit **55**. The peak-holding circuit **53** and the bottom-holding circuit **54** are configured for setting the time constants in 32 steps by the system controller **30** responsive to the spindle speed or the traversing speed.

On the other hand, the reference level signal generating circuit **55** generates a reference signal REF, having a signal level intermediate between the output signals PKH_{OUT} of the peak-holding circuit **53** and BMH_{OUT} of the bottom-holding circuit **54**, from these output signals PKH_{OUT} and BMH_{OUT}, in accordance with the equation:

$$REF=(PKH_{OUT}+BMH_{OUT})/2.$$

The level comparator circuit **56** compares the output signal AMP_{OUT} of the amplifier circuit **52**, that is the amplified traversing signal, to the reference level signal REF form the reference level signal generating circuit **55**, as to the signal level, and generates a mirror signal MIRR shown in FIG. **11**D.

Also, the RF block **21** generates disc discrimination signals DD_{PI}, DD_{AND} and $DD_{A/D}$ by a discrimination signal generating block **60** configured as shown in FIG. **12**.

This discrimination signal generating block **60** includes convert-to-binary circuits **61**, **62** for converting the focussing error signal FE=(A+C)+(B+D) and the pull-in signal PI=A+C+B+D, generated from the detection signals A, B, C and D by the detectors S_A to S_D of the eight-segment photodetector, into binary signals. The discrimination signal generating block **60** also includes an AND gate **63** for finding the logical product of output signals DD_{FE} and DD_{PI} of the convert-to-binary circuits **61**, **62** and an A/D converter **64** for converting the signal level of the pull-in signal PI into digital data. The output signal DD_{PI} of the convert-to-binary circuit **62**, the logical product signal DD_{AND} from the AND gate **63** and the output signal $DD_{A/D}$ of the A/D converter **64** are routed as disc discrimination signals to the system controller **30**.

The signals generated by the RF block **21** are routed to a convert-to-binary circuit **25**, a servo processor **31** and a discrimination signal generating circuit **27**. That is, the playback RF signals from the RF block **21** are routed to the convert-to-binary circuit **25**, while the focussing error signals FE, tracking error signals TE and the pull-in signals PI are routed to the servo processor **31**, and the disc discrimination signals DD_{PI}, DD_{AND} and $DD_{A/D}$ are routed to the system controller **30**.

The playback RF signals, obtained by the RF block **21**, are processed by the convert-to-binary circuit **25** for conversion to so-called eight-to-fourteen modulation signals (EFM signals) in case of the CD or to EFM+ signals in case of the DVD. The converted signals are routed to a decoder **26**. The decoder **26** executes EFM demodulation or CIRC decoding and, if need be, CD-ROM decoding or MPEG decoding for the information read out from the optical disc D.

The servo processor **31** generates various servo signals, such as focussing, tracking, sled or spindle servo drive signals, from the focussing error signals FE and tracking error signals TE from the RF block **21**, and from spindle error signals SPE from the system controller **30** for executing the servo operations.

That is, the focussing drive signals or tracking drive signals are generated, responsive to the focussing error signals FE and tracking error signals TE, so as to be outputted at the switch **24**. If the optical disc D is the CD **100** or DVD**120**, a terminal T_{CD} or a terminal T_{DV} of the switch **24** is selected, respectively.

During reproduction of the CD **100**, the focussing drive signals and the tracking drive signals generated responsive to the focussing error signals FE and the tracking error signals TE from the RF block **21** are routed to a biaxial driver **18***a* which then drives the biaxial mechanism **3***a* of the CD pickup **1***a*. This completes a tracking servo loop and the focussing servo loop by the CD pickup **1***a*, RF block **21***a*, servo processor **31** and the biaxial driver **18***a*.

During reproduction of the DVD **120**, the focussing drive signals and the tracking drive signals generated responsive to the focussing error signals FE and the tracking error signals TE from the RF block **21** by the servo processor **31** are routed to a biaxial driver **18***b* which then drives the biaxial mechanism **3***b* of the DVD pickup **1***b*. This completes a focussing servo loop and a tracking servo loop by the DVD pickup **1***b*, RF block **21***b*, servo processor **31** and the biaxial driver **18***b*.

The servo processor **31** routes to a spindle motor driver **19** a spindle drive signal generated responsive to a spindle error signal SPE. The spindle motor driver **19** is responsive to the spindle drive signal to apply a three-phase drive signal to the spindle motor **6** to cause the CLV rotation of the spindle motor **6**. The servo processor **31** is responsive to the spindle kick/brake control signals from the system controller **30** to start or stop the spindle motor **6** by the spindle motor driver **19**.

The servo processor **31** generates a sled drive signal, based on the sled error signal produced from the tracking error signals TE or the accessing execution control from the system controller **30** for supplying the generated sled drive signal to a sled driver **17**. The sled driver **17** is responsive to the accessing execution control to drive a sled mechanism **8**. This sled mechanism **8** is made up of the main shaft **8***a*, sled motor **8***b* and the sled transmission gears **8***c*, **8***d* and **8***e*, shown in FIG. **2** , such that optimum sliding movement of the optical pickup **1** occurs by the thread driver **17** driving the sled motor **8***b* responsive to the sled drive signal.

A laser diode **4***a* in the CD pickup la is driven by a laser driver **20***a*. On the other hand, a laser diode **4***b* in the DVD pickup **1***b* is driven by a laser driver **20***b*.

The laser drivers **20***a*, **20***b* has enclosed therein an automatic power control circuit (APC) for controlling the laser outputs of the laser diodes **4***a*, **4***b* so that a detection output of a front monitor photodiode PD adapted for detecting the light volume of the laser light radiated from the laser diodes **4***a*, **4***b* will be constant. The APC circuit is made up of, for example, three stages of amplifier circuits **71**, **72** and **73**, as shown in FIG. **13**. The APC circuit operates for amplifying a detection output of the front monitor photodiode PD by the first-stage amplifier circuit **71** and the next-stage amplifier circuit **72** for feeding back the amplified output to the output stage amplifier circuit **73** driving the laser diode LD for driving-controls the laser diode LD so that the detection output of the front monitor photodiode PD will be constant. This APC circuit has, in its initial-stage amplifier circuit **71**, a gain-switching switch SW_{APC} which is adapted for switching/setting the closed loop gain of the APC circuit between 33.2 dB and 28.8 dB as shown in FIG. **14**. The switch SW_{APC} is switching-controlled by the system controller **30** depending on the type of the optical disc D.

Specifically, the system controller **30** discriminates, based on the disc discrimination signals DD_{PI}, DD_{AND} or digitized

focussing error signals DD_{FE}, as later explained, whether the optical disc D is a single-layer disc or a double-layer disc. If the disc D is the double-layer disc lower in reflectivity than the single layer disc, the system controller **30** causes the changeover switch SW_{APC} to be changed over so that the closed-loop gain of the APC circuit will be equal to 28.8 dB. This increases the output of the laser diode **4***b*. Conversely, the single-layer disc is higher in reflectivity than the double-layer disc, such that the system controller **30** causes the changeover switch SW_{APC} to be changed over so that the closed-loop gain of the APC circuit will be equal to 33.2 dB to lower the output of the laser diode **4***b*.

If, in the case of the double layer disc, the modulated data (eight-to-sixteen modulated signal) is demodulated by the decoder **26**, the system controller **30** judges, based on the discriminating signal recorded on the signal surface of each signal recording layer, whether data being reproduced is data recorded on the first signal surface **122** or that receded on the second signal surface **123**. The second signal surface **124**, that is the signal surface separated from the disc surface **128**, has a reflectivity lower than that of the first signal surface **122** because the laser light is illuminated on the second signal surface **124** via the first signal surface **122**. Thus, if the playback signal surface is the second signal surface **124**, the system controller **30** lowers the closed-loop gain to a value lower than that for the first signal surface **122**, while raising the output of the laser diode **4***b*. Thus, gain control adapted to each signal recording layer leads to further stabilized signal reproduction.

The servo processor **31** generates a laser driving signal for effectuating laser light emission of the optical pickup **1** during reproduction under instructions from the system controller **30** to route the generated laser driving signal to the switch **23**. The switch **23** has its terminal T_{CD} and its terminal T_{DV} selected if the optical disc D is the CD **100** or the DVD **120**, respectively. Thus, the laser diode **4***a* or **4***b* emits light depending on the type of the optical disc D to be reproduced.

The above-described servo or decoding operations are controlled by the system controller **30** comprised of, for example, a micro-computer.

The operations of start or termination of reproduction track accessing, fast feed reproduction or rewind reproduction can be realized by controlling the operation of the servo processor **31** or the optical pickup **1** by the system controller **30**.

This optical disc can cope with both the CD **100** and the DVD **120**, and the optical pickup **1***a* or **1***b*, RF block **21***a* or **21***b*, laser driver **20***a*, **20***b* and the biaxial driver **18***a* or **18***b* are provided for devoted use with the CD **100** or the DVD **120**, respectively. Thus, for properly exploiting these devoted circuit systems, it is judged whether the optical disc D is the CD **100** or the DVD **120**, when the optical disc is loaded in position, for setting to one of the terminals T_{CD} or T_{DV} of each of the switches **22** to **24** under control by the system controller **30**.

Among the optical discs D handled by the present optical disc device, the CD **100** and the DVD **120** have the signal surfaces **102** and **112** at a separation of approximately 1.2 mm from the disc surfaces **105** and **116**, respectively. On the other hand, the DVD **120** has the signal surface **122** at a separation of approximately 0.6 mm from the disc surface **128**.

For explanation sake, the CD **100** and the CD-R **110** are termed a 1.2 mm single-plate disc, while the DVD **120** is termed a 0.6 mm laminated disc.

The objective lens **2***a* of the CD pickup **1***a* is moved, by focussing servo operation, in a direction towards and away from the CD **100** so that the laser light will be focussed on the signal surface **102** of the CD **100** (1.2 mm single-plate disc) as shown in FIG. **15**C.

If focussing servo control is executed directly after loading of the optical disc D, such as the CD **100** or the DVD **120**, the objective lens **2***a* first is compulsorily moved within the focussing search range for detecting focussing pull-in range corresponding to the linear area of a S-shaped curve. If the focussing servo loop is turned on with the objective lens **2***a* in the focussing pull-in range, focussing servo control is subsequently executed for convergence to the just-focus state.

These focussing search and focussing servo operations hold for a DVD optical pickup **1***b* associated with the DVD **120**.

It should be noted that the just-focus point is a point of focussing of the laser light on the signal surface **122** of the DVD**120**, which is the 0.6 mm-laminated disc, as shown in FIG. **12**C, and differs from the CD **100** as a position along the disc thickness. For both the objective lens doe CD **2***a* and the objective lens for DVD **2***b*, the focussing search range is from the bottom position of FIGS. **15**A and **16**A as far as the top position of FIGS. **15**D and **16**D. If the position of the just-focus state of FIGS. **15**C and **16**C is the initial reference position, the focussing search range is ±0.9 mm.

If the objective lens **2** (objective lens **2***a* for CD and objective lens **2***b* for DVD) can be varied in its position state relative to the CD**100** or the DVD **120**, as shown in FIGS. **15**A to **15**D or FIGS. **16**A to **16**D, the focussing error signals FE or the pull-in signals PI associated with the respective positions can be obtained as reflected light information data from the optical disc D.

In the vicinity of the just-focus point as shown in FIGS. **15**C and **16**C, the reflected light is detected at an optimum level, a S-shaped curve is observed as the focussing error signals FE, while the amplitude level is increased for the pull-in signal PI. In an assumed state of FIGS. **15**B or **16**B in which the light is focussed on the disc surfaces **105**, **128**, the reflected light is detected on the disc surfaces **105**, **128**, albeit at a low reflectivity. Thus, a small S-curve is observed as the focussing error signals FE, while a small amplitude level is observed as the pull-in signal PI.

Thus, the system controller **30** discriminates the type of the disc D for setting a parameter suited to the type of the optical disc D, based on the disc discrimination signals DD_{AND}, obtained by an AND gate **63** finding the logical product of output signals DD_{FE} and DD_{PI} of the convert-to-binary circuits **61**, **62**, output signal DD_{PI} of the convert-to-binary circuits **62** and the disc discrimination signals $DD_{A/D}$ corresponding to the digitized signal level of the pull-in signal PI by the A/D converter **64**. The convert-to-binary circuits **61** and **62** convert the focussing error signals FE=(A+C)−(B+D) and the pull-in signal PI=A+C+B+D, generated from the detection signals A, B, C and D by the detectors S_A, S_B, S_C and S_D of the eight-segment photodetector into binary-valued signals.

For example, as the objective lens **2** is compulsorily moved as in focussing search, the amplitude obtained on the signal surface of the optical disc D with the pull-in signal PI and the amplitude obtained on the disc surface are compared to each other, and the time of both amplitudes is measured for discriminating whether the optical disc D is the CD **100** or the DVD **120**. That is, since the separation from the disc surface **105** to the disc surface **102** of the 1.2 mm single-plate disc is approximately 1.2 mm, whereas the separation from the disc surface **128** to the disc surface **122** of the 0.6 mm laminated disc is approximately 0.6 mm, the time lag

between the timing of just-focussing on the disc surface to give an amplitude and the timing of just-focussing on the signal surface to give an amplitude differs between the 1.2 mm single-plate disc and the 0.6 mm laminated disc. This can be utilized for disc discrimination from, for example, the pull-in signal, as discussed in U.S. pat. application Ser. No.08/915,877 (filed on Aug. 21, 1997).

Similar discrimination can be made using the focussing error signals FE. In the present instance, the following disc discrimination operation is performed, using the binary-valued disc discrimination signals DD_{PI} converted from the pull-in signal PI by the above-mentioned convert-to-binary circuits **62**.

The system controller **30** commands the servo processor **31** to effect the driving of the objective lens **2** similar to that for focussing search. The servo processor **31** is responsive thereto to route to the biaxial drivers **18***a*, **18***b* a signal shown in FIG. **17**A as a focussing search drive signal.

In the present instance, each switch **22**, **24** has its terminal T_{DV} connected in circuit such that the operation for disc discrimination occurs using the DVD pickup **1***b*. To this end, the biaxial driver **18***b* drives the biaxial driver **3***b* by the focussing search drive signal as shown in FIG. **17**A for compulsorily raising/lowering the objective lens for DVD **2***b*.

In FIGS. **17**–**17**E, the objective lens being lowered means such a state in which the objective lens for DVD **2***b* is moved in a direction away from the optical disc D, while the objective lens being raised means such a state in which the objective lens for DVD **2***b* is moved in a direction approaching to the optical disc D. Although disc discrimination is possible with the objective lens being raised or with the objective lens being lowered, it is assumed in the following explanation that disc discrimination is made from the signal derived with the objective lens being raised.

If the objective lens **2** is moved within the focussing search range, signal amplitudes of the pull-in signal PI are observed at a timing when the objective lens **2** reaches the disc surface just focus position shown in FIGS. **15**B and **16**B and at a timing when the objective lens **2** reaches the signal surface just focus position shown in FIGS. **15**C and **16**C.

If the disc loaded is the 1.2 mm single-plate disc having a separation of approximately 1.2 mm between the disc surface **105** and the signal surface **102**, and the objective lens **2***b* is raised by the focussing search drive signal shown in FIG. **17**A, a small signal amplitude is first observed at a timing of focussing on the disc surface **105**, as shown in FIG. **17**B, whilst a larger signal amplitude is observed at a timing of focussing on the signal surface **102**. This pull-in signal is compared to a threshold value TH**1** by a comparator circuit **29** for generating a discrimination signal DD as shown in FIG. **17**C. This discriminating signal DD is routed to the system controller **30**. The system controller **30** measures the time between the pulse of the discriminating signal DD obtained at a timing associated with the disc surface **105** and the pulse of the discriminating signal DD obtained at a timing associated with the signal surface **102**. This measured time is denoted as t1.

If the disc loaded is the 0.6 mm double-plate disc having a separation of approximately 0.6 mm between the disc surface **128** and the signal surface **122**, and the objective lens **2***b* is raised by the focussing search drive signal shown in FIG. **17**A, a small signal amplitude is first observed at a timing of focussing on the disc surface **128**, as shown in FIG. **17**A, whilst a larger signal amplitude is observed at a timing of focussing on the signal surface **122**. Thus, a discriminating signal DD_{PI} shown in FIG. **17**E is routed to the system controller **30**. The system controller **30** measures the time between the pulse of the discriminating signal DD_{PI} obtained at a timing associated with the disc surface **128** and the pulse of the discriminating signal DD_{PI} obtained at a timing associated with the signal surface **122**. This measured time is denoted as t2.

That is, the different measured values t1 and t2 are obtained as tx for the 1.2 mm single-plate disc and for the 0.6 mm laminated disc, due to the difference between the disc surface and the signal surface. Thus, if the system controller 30 holds an intermediate time tTH between measured values t1 and t2, as reference value, it can be judged whether the measured time tx is ti or t2 in FIGS. **17**–**17**E, by comparing the measured time tx to the time tTH. That is, it can be judged whether the optical disc loaded is the CD **100** or the DVD **120**.

Meanwhile, similar discrimination can be made with the objective lens being lowered. The reason is that the time difference between the two pulses of the disc discrimination signals DD_{PI} is t3 in FIGS. **17**C or t**4** in FIG. **17**E depending on whether the disc D is the CD **100** or the DVD **120**. However, with the focussing search driving signal, shown in FIG. **17**A, the objective lens is lowered at a higher speed than when it is raised, such that the measured time values t3 and t4 between the two pulses of the discriminating signal DD_{PI} are shorter time values than the measured time values t1 and t2. Thus, in the instance of FIGS. **17**–**17**E, it is more meritorious for accurate discrimination to make discrimination with the objective lens being raised, although the clock frequency for counting the measured time needs to be taken into account. Such relative merit or demerit may, of course, be eliminated if the objective lens raising speed is set so as to be equal to the objective lens lowering speed. If the lowering speed is slower, it is more meritorious to make discrimination with the being lowered.

The processing by the system controller **30** in this case is hereinafter explained.

If it has not been judged whether the optical disc D loaded as the 1.2 mm single-plate disc or the 0.6 mm laminated disc, it does not matter, as a principle, which of the CD pickup **1***a* and the DVD pickup **1***b* is used first.

That is, one of the optical pickups is used for making disc discrimination in accordance with the system explained with reference to FIGS. **17**–**17**E. It does not matter which optical pickup is used for effectuating disc discrimination.

It is herein assumed that the DVD pickup **1***b* is used. Referring to FIG. **18**, an illustrative processing of the system controller **30** in which the loaded optical disc D is discriminated as the disc type and subsequently reproduced is explained with reference to FIG. **18**.

FIG. **18** shows a processing in which the power source is turned on. If the power source is turned on, and various parameters are set, by way of initializing operations, the system controller **30** waits for insertion of the optical disc D, as a first step F**101**.

If the optical disc D is inserted, processing transfers to step F**102** to set the mode to the DVD pickup mode of employing the DVD pickup **1***b*.

This mode is a mode in which each switch **22**, **24** has its terminal T_{DV} connected in circuit. The system controller **30** then proceeds to steps F**103** ff by way of disc type discrimination.

In this disc type discrimination, the DVD pickup **1***b* is used, because the DVD pickup mode is set at step F**102**.

For disc type discrimination, the DVD objective lens **1***b* is compulsorily raised or lowered within the focussing search range. This objective lens driving is started at step

F103. That is, start of outputting the focussing search drive signal such as shown in FIG. 17A is commanded. Of course, the laser outputting if the laser diode 4*b* is also started at this time.

The system controller **30**, managing control for raising or lowering the DVD objective lens 1*b* within the focussing search range, detects the disc discrimination signals DD supplied from the discrimination signal generating circuit **27**, at step F104, for measuring the time period between two pulses shown in FIGS. 17C and 17E.

There are occasions wherein, due for example to too low reflection level on the disc surface, two pulses as the disc discrimination signals DD are not correctly observed during raising or lowering of the DVD pickup 4*a*. In such case, a measurement error is deemed to have occurred at step F105 such that processing reverts to step F103 to effectuate again the objective lens driving and measurement. In actuality, limitations are preferably placed on the number of times of re-trial operations on occurrence of the measurement errors without allowing an arbitrary number of times of the retrial operations.

After measuring the time period between two pulses of the discriminating signal DD_{PI}, the measured time value is compared at step F106 to the time tTH as the reference value. If, as a result of the comparison, the measured value is longer, it is judged at step F108 that the optical disc D is the 1.2 mm single-plate disc, that is the CD **100**.

Since the DVD pickup 1*b* has been used for the discriminating operation, the result of judgment indicates that this state is not in meeting with the currently loaded optical disc D (CD **100**). Thus, the mode is switched at step F108 to the CD pickup mode. That is, the mode is set in which each of the switches **22** to **24** has its terminal T_{CD} connected in circuit and the CD pickup 1*a* is in use.

Conversely, if As the result of comparison at step F106, the reference time tTH is longer, it is judged at step F107 that the optical disc D is the 0.6 mm laminated disc, that is the DVD **120**.

If the disc D is judged to b the DVD **120**, the pickup mode state is not changed, because the DVD pickup mode has already been set.

If the pickup mode setting in meeting with the disc discrimination and the results of disc discrimination has come to a close, processing transfers to actual playback operation. That is, focussing search is started at step F109 to start the focussing search to pull-in the focussing servo. After the pull-in of the focussing servo has been terminated, processing transfers to step F110 and step F111 to carry out other starting operations. That is, processing of the servo system, such as adjusting the rotation of the spindle motor **6** and turning on of the tracking servo, is completed, while the readout of the optical disc D is enabled. In addition, the necessary management information recorded on the optical disc D such as TOC, is read. After completion of these processing operations, processing transfers to step F112 to reproduce the CD **100** or the DVD **120**.

Since the signal level of the pull-in signal PI=A+C+B+D is varied with reflectivity of the optical disc D, the system controller **30** calculates the reflectivity of the optical disc D from the disc discrimination signals $DD_{A/D}$ at a time point of completion of focussing servo pull-in. The system controller **30** switching-controls the changeover switch SW_{APC} of the APC circuit enclosed in the laser drivers **20***a*, **20***b*, depending on the reflectivity of the optical disc D, for switching the closed-loop gain of the APC circuit between the single-layer disc and the double-layer disc. This enables the laser light of the optimum power from the laser diode LD of the optical pickup **1** to the single-layer disc and the double-layer disc to read out signals in stability from the optical disc D by the optical pickup **1** to produce playback RF signals with optimum S/N ratio.

The disc discrimination signals $DD_{A/D}$ can also be used for discriminating the optical discs D having different reflectivities with difference in the material of the recording layer making up the signal surface, such as CD and CD-RW or DVD and DVD-RW.

Referring to FIGS. 17–17E, if the objective lens **2** is compulsorily moved with in the focussing search range by the biaxial drivers **18***a*, **18***b*, by way of performing a focussing search operation, a sole S-curve is obtained as the focussing error signal FE and a pull-in signal PI is obtained within the range of the S-curve, as shown in FIGS. **19**A and **19**C, respectively, for a single-layer disc, whereas two S-curves are obtained as the focussing error signal FE and a pill-in signal is obtained astride the two s-curves, as shown in FIGS. **20**A and **20**C, respectively for a double-layered disc. It is noted that the focussing error signal FE and the pull-in signal PI are generated from the detection signals A, B, C and D by the detectors S_A, S_B, S_C and S_D of the eight-segment photodetector by the equations FE=(A+C)–(B+D) and PI=A+C+B+D, respectively. The focussing error signal FE and the pull-in signal are converted by the convert-to-binary circuits **61**, **62** to find the logical product by the AND gate **63**. That is, the pull-in signal PI=A+C+B+D, a sum signal of the detection signals A to D by the above photodetector, is converted to binary-valued signal at a pre-set level to generate the disc discrimination signals DD_{PI} shown in FIGS. **19**D, **20**D as discriminating pulses, the number of which is counted during the gating period supplied by the gate pulse for discriminating the types of the optical discs D of different numbers of the signal recording layers based on the results of the counting. It is noted that, in the single-layer disc, the disc discrimination signal DD_{AND} goes high 'H' only once by a sole focussing search operation, as shown in FIG. **19**E, whereas, in the double-layer disc, the disc discrimination signal DD_{AND} goes high 'H' twice by a sole focussing search operation, as shown in FIG. **20**E. This discriminating operation enables discrimination of the optical disc D with variable reflectivities which is more accurate than that by the disc discrimination signals $DD_{A/D}$ representing the signal level of the pull-in signal.

That is, the system controller **30** can discriminate between the single-layer disc and the double-layer disc by the disc discriminating operation in accordance with the flowchart shown in FIG. **21**.

Specifically, if the disc discriminating operation is started, it is judged at step S1 whether the input, that is the disc discrimination signals DD_{AND}, has gone high 'H'. If the input is 'H', processing transfers to step S2.

At this second step S2, it is judged whether or not the input, that is the disc discrimination signals DD_{AND}, is low 'L'. If the input is at logic 'L', processing transfers to step S3.

At this third step S3, it is judged whether or not the input, that is the discrimination signal DD_{AND}, has become logical H. When the input becomes logical H, processing transfers to step S4.

At this step S4, it is judged whether or not the input, that is the disc discrimination signals DD_{AND}, again is low 'L', if the input is logical 'L', processing transfers to step S5 to set parameters of various circuits associated with the double-layer disc.

If the result of decision at step S3 is NO, that is if the input is not again 'H', processing transfers to step S6.

At this sixth step S6, it is judged whether or not the number of times of repetition of the decision processing at the third step S3 is 100. If the result is NO, that is if N is not equal to 100, processing transfers to step S7 to wait for 1 ms. At the next step S8, N is set to N=N+1. Then, processing reverts to step S3. The decision processing of this third step S3 is repeated. If the result of decision at the sixth step S6 is YES, that is if N=100, that is if the pulse of the disc discrimination signals DD_{AND} corresponding to the second layer is not obtained after lapse of 100 ms, processing transfers to step S9 to set parameters of respective circuits associated with the single-layer disc.

In the above-described embodiment, three types of the disc discrimination signals $DD_{A/D}$, DD_{PI} and DD_{AND} are used for discriminating the types of the optical discs D. The disc discrimination signal $DD_{A/D}$ is obtained by converting the signal level of the pull-in signal PI into digital data, whereas the disc discrimination signal DD_{PI} is obtained by converting the pull-in signal PI into binary-valued signal and the disc discrimination signal DD_{AND} is obtained by AND-ing the binary-valued version of the focussing error signal FE with the disc discrimination signal DD_{PI}. Alternatively, the disc discrimination signals DD_{PI} obtained on converting the pull-in signal into binary-valued signal and the disc discrimination signals DD_{FE} obtained on converting the signal level of the focussing error signal FE into digital data may also be used for disc discrimination, as shown in the flowcharts of FIGS. 22 and 23. In this case, the focussing error signal FE is directly supplied to an A/D input port of the system controller 30.

As an operating example of using the DVD pickup 1*b*, an illustrative processing of the system controller 30 in which the type of the loaded optical disc D is discriminated on power up of the loaded optical disc device before proceeding to reproduction is explained with reference to FIGS. 22 to 24.

FIG. 22 is a flowchart showing the operation since power up until reproduction.

If the power source is turned on, and various parameters are first set, by way of initialization, the system controller 30 at step F201 first turns the laser diode 4*b* on. Then, at step F202, the system controller 30 compulsorily lowers the optical pickup for DVD 1*b* within the focussing search range at an optical axis position furthest away from the optical disc D. At step F203, the signal level of the focussing error signal FE, with the optical pickup for DVD 1*b* lying at the position furthest from the optical disc D, is sampled, with the sampled value being set as reference value FE_o.

At the next step F204, a focussing search timeout measurement timer is started. This focussing search timeout is set for preventing the voltage from being continuously applied across the focussing control in case of non-detection of the reflected light from the signal surface of the optical disc D and for preventing the system controller 30 from polling without proceeding to the next processing. The focussing search timeout is herein set to 800 ms.

At step F205, the search operation of raising the optical pickup for DVD 1*b* is started.

At step F206, it is judged whether or not the disc discrimination signals DD_{PI} is at logical 'H'. Since the disc discrimination signals DD_{PI} is a binary-valued version of the pull-in signal PI representing the light volume of the reflected light by the optical disc D, the logical 'H' is set for the state of detection of the surface or the reflected light from its signal surface, if the optical disc D is loaded in position.

If the result of judgment at step F206 is NO, that is if the disc discrimination signals DD_{PI} s not at logical 'H', processing transfers to step F207 to judge whether or not the value of the focussing search timeout timer has reached 800 ms to reach timeout. If timeout has not been reached, processing reverts to step F206 so that the decision of the disc discrimination signals DD_{PI} is repeated until timeout of the focussing search timeout timer. If the result of decision at step F207 is YES, that is if the focussing search timeout timer has timed out, a decision is given that the optical disc D has not been loaded and processing transfers to step F208 to display an indication such as 'no disc'.

If the result of decision at step F206 is YES, that is if the disc discrimination signals DD_{PI} is at logic 'H', a decision is given that the optical disc D has been loaded in position. Thus, processing transfers to the next step F209 to start a disc discrimination timer and to start capturing of the signal level of the focussing error signal FE. At this step F209, it is detected that the disc discrimination signals DD_{PI} has become logical 'H' based on the reflected light from the surface of the optical disc D.

At the next step F210, it is judged whether or not the focussing search timeout timer has reached 800 ms and timed out. If the timer has not timed out, processing transfers to step F211 to check whether or not the disc discrimination signals DD_{PI} is at logical 'H'. If the result of decision at step F210 is YES, that is if the focussing search timeout timer has timed out, a decision is given that the optical disc D has not been loaded. Thus, processing transfers to the above step F208 to display an indication such as 'no disc'.

At step F211, it is judged whether or not the disc discrimination signals DD_{PI} is at logical 'H'. At this step F211, it is detected that the disc discrimination signals DD_{PI} is at logical 'H' by the reflected light from the signal surface of the optical disc D.

At the next step F212, it is judged whether or not the value of the disc discrimination timer is smaller than the reference time tTH. Specifically, at this step F212, it is judged whether or not the time which elapses since the disc discrimination signals DD_{PI} is judged at step F206 by the reflected light from the surface of the optical disc D to be logical 'H' until the disc discrimination signals DD_{PI} is judged at step F211 by the reflected light from the signal surface of the optical disc D to be logical 'H' is smaller than the reference time tTH. If the result of decision at this step F212 is NO, that is if the value of the disc discrimination timer is longer than the reference time tTH, the loaded optical disc D is judged to be a 1.2 mm single-plate disc, that is CD 100. Thus, processing transfers to step F213 to switch to the CD pickup mode of employing the CD pickup 1*a*.

If the result of decision at this step F212 is YES, that is if the value of the disc discrimination timer is shorter than the reference time tTH, the loaded optical disc D is judged to be a 0.6 mm laminated disc, that is DVD 120. Thus, processing transfers to step F214 to make disc discrimination of whether the DVD 120 is the single-layered disc or a double-layered disc in accordance with the flowchart shown in FIG. 23.

If the pickup mode setting corresponding to the disc discrimination and the results of the disc discrimination have come to a close, the system controller proceeds to actual reproducing processing. Specifically, the focussing search is started at step F215 for focussing servo pull-in. At step F216, it is judged whether or not focussing servo pull-in has been completed. If the result of judgment is YES, processing transfers to step F217 to perform other starting operations. That is, processing of the servo system, such as adjusting the rotation of the spindle motor 6 and turning on of the tracking servo, is completed, while the readout of the optical disc D

is enabled. In addition, the necessary management information recorded on the optical disc D such as TOC, is read. After completion of these processing operations, processing transfers to step F**218** to reproduce the CD **100**, DVD **120** or the DVD-RW.

The system controller **30** commands the servo processor **31** to drive the objective lens **2** as in the case of the focussing search. The servo processor **31** is responsive thereto to supply to the biaxial driver **18***b* a signal shown in FIG. **24**A as a focussing search drive signal to drive the biaxial driver **3***b* for compulsorily raising the objective lens for DVD **2***b*. During the period when the disc discrimination signals DD_{PI} is at logical 'H' it is judged how many times the S-curve is detected as being the focussing error signal FE using the first and second threshold values $TH__H$ and $TH__L$, for discriminating between the single-layer disc and the double-layer disc.

That is, in the processing for discriminating between the single-layer disc and the double-layer disc, a focussing error timeout timer is first started at the first step **S11**. This focussing search timeout is set for preventing the system controller **30** from polling without proceeding to the next processing in case of failure in detecting the S-curve as the focussing error signal FE during the logical 'H' period of the disc discrimination signals DD_{PI}. The focussing search timeout is herein set to 40 ms.

At the second step **S12**, it is judged whether or not the focussing error timeout timer has timed out. If the focussing error timeout timer has timed out, it is judged that a detection error has occurred, and processing transfers to step **S13** to perform error processing. If the result of decision at the second step **S12** is NO, that is if the focussing error timeout timer has timed out. Processing transfers to a fourth step **S14**.

At the fourth step **S14**, the focussing error signal FE is captured via an A/D port to judge whether or not the signal level is larger than the first threshold value $TH__H$. If the result of decision at the fourth step **S14** is NO, that is if the signal level of the focussing error signal FE is smaller than the first threshold value $TH__H$, processing reverts to the second step **S12** to repeat the decision of timeout of the focussing error timeout timer. If the result of decision at te fourth step **S14** is YES, that is if the signal level of the focussing error signal FE is larger than the first threshold value $TH__H$, processing reverts to the fifth step **S15**.

At the fifth step **S15**, it is judged whether or not the focussing error timeout timer has timed out. If the focussing error timeout timer has timed out, a detection error is judged to have occurred, such that processing transfers to a third step **S13** to perform error processing. If the focussing error timeout timer has not timed out, processing transfers to a sixth step **S16**.

At this sixth step **S16**, the focussing error signal FE is captured via an A/D port to judge whether or not the signal level is smaller than the second threshold value $TH__L$. If the result of decision at this sixth step **S16** is NO, that is if the signal level of the focussing error signal FE is larger than the second threshold value $TH__L$, processing reverts to te fifth step **S15** to repeat the decision of timeout of the focussing error timeout timer. If the result of decision at this sixth step **S16** is YES, that is if the signal level of the focussing error signal FE is smaller than the second threshold value $TH__L$, processing reverts to the seventh step **S17**.

At this seventh step **S17**, it is judged whether or not the disc discrimination signal DD_{PI} is at the logical 'L'. If the result of judgment at this step **S17** is YES, that is if the disc discrimination signal DD_{PI} is at the logical 'L', it is judged that the disc is the single-layer disc in which the S-curve of the focussing error signal FE is detected only once during the logical 'H' period of the disc discrimination signal DD_{PI}. Thus, processing transfers to the eighth step **S18** to set parameters of various circuits. If the result of judgment at this step **S17** is NO, that is if the disc discrimination signal DD_{PI} is at the logical 'H', processing transfers to a ninth step **S19**.

At this ninth step **S19**, t is judged whether or not the focussing error timeout timer has timed out. If the timer has timed out, it is judged that a detection error has occurred, and processing reverts to the third step **S13** to perform error processing. If the result of judgment at step **S19** is NO, that is if the focussing error timeout timer has not timed out, processing transfers to a tenth step **S20**.

At this tenth step **S20**, the focussing error signal FE is captured via A/D port to judge whether or not its signal level is larger than a first threshold value $TH__H$. If the result of judgment at this tenth step **S20** is NO, that is if the signal level of the focussing error signal FE is smaller than the first threshold value $TH__H$, processing reverts to the ninth step **S19** to repeat the decision of the timeout of the focussing error timeout timer. If the result of judgment at the tenth step s**20** is YES, that is if the focussing error signal FE is larger than the first threshold value $TH__H$, processing transfers to the eleventh step **S21**.

At this eleventh step **S21**, it is judged whether or not the focussing error timeout timer has timed out. If the timer has timed out, a detection error is judged to have occurred, and accordingly, processing transfers to the third step **S13** to perform error processing. If the result of decision at the eleventh step **S21** is NO, that is if the timer has not timed out, processing transfers to the twelfth step **S22**.

At this twelfth step **S22**, the focussing error signal FE is captured via A/D port to judge whether or not its signal level is smaller than a second threshold value $TH__L$. If the result of decision at this step **S22** is NO, that is if the signal level of the focussing error signal FE is larger than the second threshold value $TH__L$, processing reverts to the eleventh step **S21** to repeat the decision on timeout of the focussing error timeout timer. If the result of decision at this step **S22** is YES, that is f the signal level of the focussing error signal FE is smaller than the second threshold value $TH__L$, the disc D is judged to be a double-layer disc in which a S-curve of the focussing error signal FE is detected twice during the logical 'H' period of the disc discrimination signal DD_{PI}, as shown in FIG. **24**C. Thus, processing transfers to a thirteenth step **S23** to set parameters for various circuits associated with the double-layer disc.

The first and second threshold values $TH__H$ and $TH__L$ are given as

$$TH__H = FE_o + W$$

$$TH__L = FE_o - W$$

where W is the width of a detecting window and FE_o is the reference value captured at the above step F**203**.

Thus, as shown in FIG. **24**D, even if an offset is caused in the focussing error signal FE directly entering the A/D input port of the system controller **30**, it is cancelled to enable correct disc discrimination.

Thus, with the optical disc device of the present invention, in which the closed-loop gain of the automatic power control means is controlled by control means to a gain corresponding to the reflectivity of the optical disc, based on the detection output of photodetector means when the focussing is applied to the signal surface of the optical disc, a laser

light beam of an optimum power can be stably illuminated on plural sorts of the optical discs. Thus, signals can be read out in stability from the optical disc by the photodetector means, thus giving playback RF signals with superior S/N ratio.

By discriminating the sorts of plural optical discs with different numbers of the signal recording layers by disc discriminating means based on the focussing error signals generated by the focussing control means on moving the objective lens by focussing search by the focussing control means along the optical axis for focussing search, and by setting the operating mode in meeting with the disc type by the control means based on the discrimination output, plural sorts of the optical discs can be reproduced reliably.

By illuminating the laser light on the signal surface of the optical disc via objective lens, and by detecting the reflected light of the laser light from the signal surface of the disc, disc types with different numbers of the signal recording layers can be discriminated easily based on the focussing error signals generated from the detection signals.

Since the operating characteristics of the tracking control means can be switched responsive to the disc types by the control means based on the decision output of the disc discrimination means, tracking control can be performed reliably on the plural disc types having different reflectivities.

Since the operating characteristics of the mirror signal generating means can be switched responsive to the disc types by the control means based on the decision output of the disc discrimination means, mirror signals can be reliably produced for the plural disc types by the mirror signal generating means.

Since the detection system of the tracking control means can be switching-set responsive to the disc types by the control means based on the decision output of the disc discrimination means, tracking control can be performed reliably on the plural disc types having different reflectivities.

What is claimed is:

1. An optical disc device comprising:

a laser light source for radiating a laser light beam illuminated on a signal surface of an optical disc via an objective lens;

photodetector means for detecting the light of the laser light radiated by said laser light source and reflected from the signal surface of the optical disc;

focussing control means for displacing said objective lens responsive to a focussing error signals generated on the basis of a detection output by said photodetector means for controlling the focussing state of the beam spot of said laser light beam on said signal surface;

disc discrimination means for discriminating the types of the optical discs, based on said focussing error signals, when said objective lens is moved by said focussing control means along the optical axis for focussing search; and

control means for setting an operating mode in meeting with the disc types based on a discrimination output by said disc discrimination means,

wherein said photodetector means has a photodetector split in at least four segments;

said focussing control means performing focussing control based on a focussing error signal FE=(A+B)−(C+D) in which A, B, C and D denote detection signals of the four segments of said photodetector;

said disc discrimination means generating a gating pulse by converting a sum signal PI=A+B+C+D of said detection signals A to D of said photodetector at a pre-set level into binary-valued signals at a pre-set level, said disc discrimination means converting the focussing error signals FE into binary-valued signals for generating discriminating pulses said disc discrimination means counting the discriminating pulses during a gating period supplied by said gating pulse for discriminating the disc types of different number of recording layers based on the counted results.

2. The optical disc device as claimed in claim **1** further comprising:

convert-to-binary means for converting the signal level of said focussing error signals into binary-valued signals by comparing the signal level of said focussing error signals to pre-set positive and negative levels, said disc discrimination means discriminating the number of times of appearance of the binary-valued focussing error signals for discriminating the disc types.

3. The optical disc device as claimed in claim **1**, wherein said disc discrimination means sets a threshold level for conversion to binary depending on a window width of said gating pulse.

4. The optical disc device as claimed in claim **1** wherein said disc discrimination means detects the separation between the disc surface and the signal surface based on a detection output of said return light detection means for discriminating the plural optical discs of different substrate thicknesses based on the detected separation.

5. The optical disc device as claimed in claim **1** wherein said focussing control means outputs focussing search signals for displacing the objective lens in a direction along the optical axis, said disc discrimination means discriminating the types of the optical discs based on an output timing from said return light detection means during the time said focussing control means is outputting focussing search signals.

6. The optical disc device as claimed in claim **1** wherein said disc discrimination means discriminates between a single-layer disc having a sole signal surface and a double-layer disc having two signal surfaces.

7. The optical disc device as claimed in claim **1**, wherein said disc discrimination means discriminates between plural optical discs of different numbers of signal recording layers based on the focussing error signals detected when said focussing control means displaces said objective lens in a direction approaching said optical disc.

8. The optical disc device as claimed in claim **1** wherein said disc discrimination means discriminates between a first optical disc having a substrate of a first thickness and a second optical disc having a substrate of a second thickness smaller than said first thickness.

9. An optical disc device for illuminating laser light on a signal surface of an optical disc via an objective lens for reproducing signals recorded on said signal surface, comprising:

focussing control means for displacing said objective lens from a first position displaced from the optical disc along an optical axis thereof to a second position closer to said optical disc; and

disc discriminating means for discriminating whether the optical disc is a single-plate disc or a laminated disc, based on the reflected light from the surface of the optical disc and on the reflected light from the signal surface, during the time period when said objective lens is moving from said first position to said second position, said disc discriminating means also discriminating whether the optical disc is a single—layer disc

or a double-layer disc, based on the focussing error signals detected during said time period,

wherein the reflected laser light is detected be a photodetector split into at least four segments; and

wherein said disc discriminating means includes a focussing error signal converting means for converting a focussing error signal obtained from detection signals A, B, C and D of said four-segment photodetector for generating a discriminating pulse and converting a sum signal PI=A+B+C+D of said detection signals A to D of said photodetector at a pre-set level into binary-valued signals for generating gating pulses and a discriminating pulse counting means for counting the discriminating pulses during the gating period supplied by said gating pulse for discriminating the disc types of different numbers of recording layers based on the counted results.

10. A method for discriminating an optical disc comprising:

a generating step of illuminating a laser light beam on a signal surface of the optical disc via an objective lens;

a generating step of detecting the reflected light of the laser light from the signal surface of the optical disc as said optical disc is displaced along the optical axis for generating a focussing error signal from a detected output; and

a discriminating step of discriminating the disc types having different numbers of the signal recording layers, including the signal surface, based on the generated focussing error signals,

wherein, in said generating step, the reflected laser light is detected by a photodetector split into at least four segments; and

wherein said discriminating step includes a sub-step of converting a focussing error signal obtained from detection signals A, B, C and D of said four-segment photodetector for generating a discriminating pulse and converting a sum signal PI=A+B+C+D of said detection signals A to D of said photodetector at a pre-set level into binary-valued signals for generating gating pulses and a sub-step of counting the discriminating pulses during the gating period supplied by said gating pulse for discriminating the disc types of different numbers of recording layers based on the counted results.

11. An optical disc device, comprising:

a laser light source for radiating a laser light beam illuminated on a signal surface of an optical disc via an objective lens;

photodetector means for detecting light of the laser light radiated by said laser light source and reflected from the signal surface of the optical disc;

focusing control means for displacing said objective lens responsive to focusing error signals generated on the basis of a detection output by said photodetector means for controlling the focusing state of the beam spot of said laser light beam on said signal surface;

disc discrimination means for discriminating the type of the optical disc, based on said focusing error signals, when said objective lens is moved by said focusing control means along the optical axis for focusing search; and

control means for setting an operating mode in meeting with the disc types based on a discrimination output by said disc discrimination means,

wherein said disc discrimination means generates a gating pulse by converting the detection output by said photodetector means into binary valued signals at a pre-set level, said disc discrimination means converting the focusing error signals into binary valued signals for generating discriminating pulses, said disc discrimination means counting the discriminating pulses during a gating period supplied by said gating pulse for discriminating the disc type based on the counted results.

12. The optical disc device as claimed in claim **11**, wherein said disc discrimination means discriminates between a first optical disc having a substrate of a first thickness and a second optical disc having a substrate of a second thickness smaller than said first thickness.

13. The optical disc device as claimed in claim **11**, further comprising:

convert-to-binary means for converting the signal level of said focussing error signals into binary-valued signals by comparing the signal level of said focussing error signals to pre-set positive and negative levels, said disc discrimination means discriminating the number of times of appearance of the binary-valued focussing error signals for discriminating the disc types.

14. The optical disc device as claimed in claim **11**, wherein said disc discrimination means sets a threshold level for conversion to binary depending on a window width of said gating pulse.

15. The optical disc device as claimed in claim **11**, wherein said disc discrimination means detects the separation between the disc surface and the signal surface based on a detection output of said return light detection means for discriminating plural optical discs of different substrate thicknesses based on the detected separation.

16. The optical disc device as claimed in claim **11**, wherein said focussing control means outputs focussing search signals for displacing the objective lens in a direction along the optical axis, said disc discrimination means discriminating the type of the optical disc based on an output timing from said return light detection means during the time said focussing control means is outputting focussing search signals.

17. The optical disc device as claimed in claim **11**, wherein said disc discrimination means discriminates between a single-layer disc having a sole signal surface and a double-layer disc having two signal surfaces.

18. The optical disc device as claimed in claim **11**, wherein said disc discrimination means discriminates between plural optical discs of different numbers of signal recording layers based on the focussing error signals detected when said focussing control means displaces said objective lens in a direction approaching said optical disc.

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